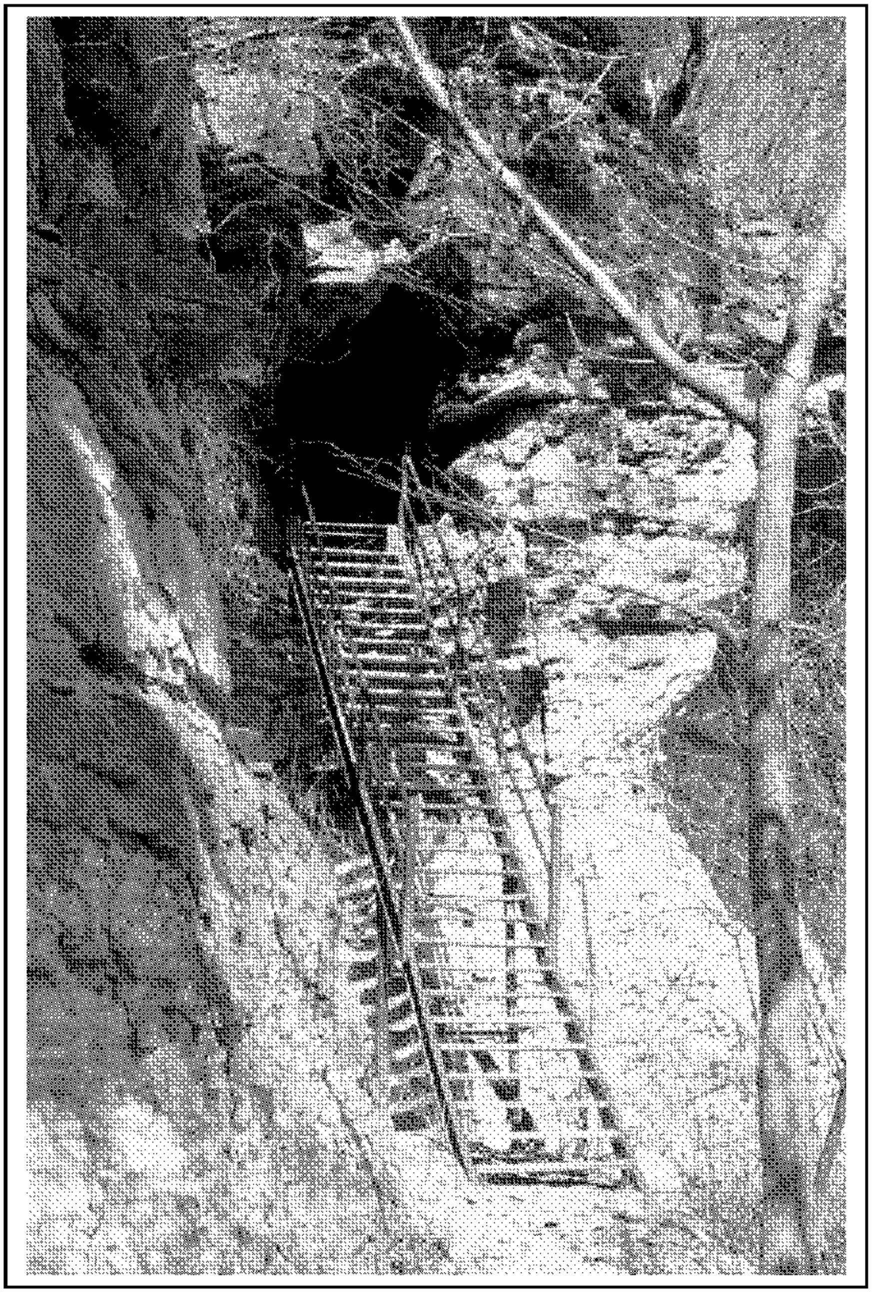
CLASSIC GEOLOGY OF THE BURLINGTON AREA: DES MOINES COUNTY, IOWA

by Brian J. Witzke and Stephanie Tassier-Surine



Geological Society of Iowa

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Cover photograph: Photograph of the stairs leading up to Starr's Cave. The cave is a solutional enlargement of a fracture in the lower Dolbee Creek Member of the Burlington Formation and in the unnamed "upper member" of the Wassonville Formation.

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INTRODUCTION

Geological Society of Iowa Spring 2001 field trip will revisit exposures that have been critical in the development of our understanding of Mississippian and Quaternary strata, not only in Iowa, but worldwide. First we will visit outcrops of Mississippian Osagean and Kinderhookian strata at Crapo Park in Burlington. The exposures in the Burlington area include the types sections of the Burlington Formation and other Mississippian units. Charles Keyes, Iowa Geological Survey geologist who wrote the report on the Geology of Des Moines County in 1895 recognized the importance of these exposures. He wrote:

> *The strata along the Mississippi river in the vicinity of Burlington have become classic in American geologic literature. Wherever these rocks are known the Burlington limestone is a familiar term. It was at the city of Burlington that they were first studied carefully and described in detail. This place, consequently, becomes the typical locality; and with the section at this point all beds of this age in other regions must be compared.*

Charles Roland Keyes, 1895,
Geology of Des Moines County, p 431

We will see the same strata at the second stop of the field trip along Flint Creek at Starr's Cave State Preserve just north of Burlington. These exposures were designated as the type section for the Starr's Cave Formation and have served as key exposures in the training of University of Iowa geology students for over a century. The Mississippian section at Starr's Cave, as described by University of Iowa geology professor Brian Glenister and others, was included with some of the most important geologic exposures in the north-central U.S. in the Geological Society of America's Decade of North American Geology Centennial Field Guide Volume 3 published in 1987.

The third field trip stop will examine the Pleasant Grove Exposure, a cut-bank exposure of the Illinoian Glasford Formation Kellerville Till Member, which overlies Pre-Illinoian Hickory Hills Till Member of the Wolf Creek Formation. This exposure was first described by Iowa Geological Survey geologist George Hallberg and others in the classic 27th Midwest Friends of the Pleistocene field conference in 1980. The guidebook included the redefinition of the Yarmouth Paleosol, a key soil horizon that developed on Pre-Illinoian sediments prior to the advance of the Illinoian glacier.

The revisiting of these classic sections in this Spring's field trip will give Geological Society of Iowa members and friends an opportunity to reexamine these key exposures and discuss the characteristics that make them so important.

DEVELOPMENT OF THE MISSISSIPPI RIVER IN SOUTHEAST IOWA

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INTRODUCTION

The configuration of tributaries and the position of the Mississippi River have changed numerous times throughout the Quaternary. Certain aspects of the history of the Mississippi River are poorly understood, but many studies have speculated on the Mississippi River positions and its response to the glacial advances of the Quaternary.

PRE-ILLINOIAN

Prior to the Illinoian ice advance, the Mississippi River may have been diverted several times by Pre-Illinoian events, but this history is difficult to sort out. It is known that the Mississippi River did not follow its present course south of Clinton, Iowa, prior to the Illinoian (Udden, 1899; Trowbridge, 1959; Anderson, 1968). Instead, it turned to the southeast, following through the Meredosia Channel between the modern Mississippi and Rock River valleys in Illinois. It then flowed into the Princeton Bedrock Channel, and joined with the present Illinois Valley in the vicinity of Hennepin, Illinois. At that time, no valley existed between Rock Island and Muscatine, and the present course of the Mississippi River below Muscatine was occupied by the ancestral Cedar, Iowa, Skunk, and Des Moines Valleys (Udden, 1899; Horberg, 1950; Hansen, 1973).

Multiple Pre-Wisconsin drainage lines exist in southeastern Iowa as evidenced by deep valleys cut into the bedrock surface. The most prominent of these is the Cleona Channel, which trends southwesterly across the western part of Muscatine County. The Cleona Channel joins the Udden Channel in Louisa County (Hansen, 1972). Both of these valleys contain Pre-Illinoian tills and multiple buried valley fills (Bettis, 1994; Bettis and Autin, 1997). The Udden Channel was buried by the Illinoian glacial advance. The Cleona Channel was ice-marginal during the Illinoian and carried the diverted Mississippi River flow. Neither channel is occupied by a large stream today.

ILLINOIAN

During the advance of the Illinoian age Lake Michigan Lobe, ice blocked the Princeton Channel and a large lake, Glacial Lake Moline, formed upstream in what is now the Green River Lowland of Rock Island County, Illinois (Anderson, 1968). The Mississippi River was diverted from its interglacial course in the Princeton Bedrock Valley of Illinois to the Cleona Channel between Dixon and Wilton in eastern Iowa (Anderson, 1968; Bettis and Glenister, 1987; Bettis and Autin, 1997). The Illinoian glacier advanced from the northeast out of the Lake Michigan Basin and moved across Illinois into Iowa. During the early Illinoian, ice covered what is currently the Mississippi channel from Clinton to Fort Madison, Iowa. The westernmost margin of the advance ranged from approximately 4 miles near Muscatine to 20 miles north of Burlington (Kay and Graham, 1943). At the maximum extent of the Illinoian glaciation, ice blocked the lower reaches of the Iowa and Cedar Valleys and also the Wapsipinicon River Valley farther to the north. A series of diversion channels developed between the Maquoketa and Wapsipinicon (Goose Lake Channel) and the Wapsipinicon and Cedar (Cleona Channel) Valleys (Anderson, 1968).

Several outlets for Lake Moline developed as the Illinoian ice continued to advance, but were subsequently buried (Anderson, 1968). Portions of the Edwards Valley, Copperas Creek, and Andalusia Gorge of the present Mississippi Valley provided outlets for the ice-dammed lake. Nott (1981) and Hallberg et al. (1980) have also shown that portions of Crooked Creek, the Skunk River, Cedar Creek, and Sugar Creek (collectively known as the Leverett Channel of Schoewe, 1921) carried meltwater to the south from the Illinoian front.

SANGAMON

At the end of the Illinoian glaciation, the Mississippi River returned to its course through the Princeton Bedrock Channel and down the present Illinois River Valley (Anderson, 1968). Downcutting, headward extension, and drainage network development continued from the end of the Illinoian stage to approximately 55,000 years ago to form the modern configuration of the major tributary valleys in Iowa. The Sangamon Geosol also developed on the stable uplands and valley surfaces at this time.

LATE WISCONSINAN

The last major episode influencing the drainages in southeastern Iowa occurred approximately 21,000 years ago. Glacial ice of the Lake Michigan Lobe again blocked the Ancient Mississippi in the Princeton Channel in Illinois and formed Glacial Lake Milan in the Green River Lowland of northeastern Illinois (Schaffer, 1954; Anderson, 1968). Lake Milan eventually deepened to the elevation of a low divide and drained through the Andalusia Gorge located between Rock Island and Muscatine. The Mississippi River changed its course to the present route through the Andalusia Gorge and south through the Ancestral Iowa/Cedar Valley to St. Louis, where it joins the pre-Wisconsinan course of the Mississippi Valley (Hobbs, 1990; Bettis, 1997).

Between 21,000 to 11,000 B.P. the Mississippi Valley was aggraded by outwash from glaciers in the northern part of the Mississippi Basin and the Lake Michigan Basin. During this time, outwash accumulated in the Green River Lowland and extended into the Andalusia Gorge (the modern Mississippi River valley), which was carrying meltwater and lake discharge. The Andalusia was cut down to about its present level at this time and linked the Ancient Mississippi above Rock Island with the Ancient Iowa valley below Muscatine (Anderson, 1968). Following the retreat of the ice and the cessation of meltwater and outwash discharge into the Green River Lowland, the Mississippi River continued to flow through the Andalusia Gorge and the modern configuration of the valley was established.

In the area between Rock Island and Burlington the aggradation was interrupted by down-cutting events around 13,000 and 10,500 B.P. These down-cutting events resulted in the development of two late glacial terraces: the Savanna Terrace (an older, higher level) and the Kingston Terrace (younger and lower level). These terraces have previously been referred to as the Mankato and Late Mankato terraces (Trowbridge, 1954; Edmund and Anderson, 1968).

The Savanna Terrace remnants are recognized along the length of the Mississippi Valley from the St. Croix River to the Meramac River south of St. Louis (Hobbs et al., 1990). Radiocarbon dates of terrace sediments indicate that the Savanna Terrace was accumulating 17,000 years ago (Bettis and Hallberg, 1985). Stratigraphic relationships with other radiocarbon dated alluvial deposits indicate that the Savanna Terrace deposition ended between 12,000 and 11,500 years ago.

Floods occurred when meltwater from glaciers in Minnesota and Wisconsin was discharged into the Mississippi Valley. Floods originating from the Lake Superior Basin carried distinctive reddish brown clay derived from the Upper Keweenan Fon du Lac Formation, whereas floodwaters from other sources did not. Most of the fill comprising the Savanna Terrace consists of gray and grayish brown silt, loam and sand that is a combination of non-Superior-source flood sediment and locally-derived alluvium (Bettis, 1997).

Following the down-cutting of the Savanna Terrace, outwash continued to accumulate, and the Mississippi floodplain aggraded until about 10,500 B.P. when glacial meltwater was no longer directly discharged into the Upper Mississippi Valley. The Mississippi River had downcut to within a few meters of its present floodplain level by 11,000 years ago. Around 10,500 B.P. another down-cutting episode isolated the latest glacial floodplain and formed the Kingston Terrace. The discharge of large volumes of sediment-free meltwater as a result of the opening of the southern outlet of Glacial Lake Agassiz may have been the cause. Glacial Lake Agassiz was located in the Red River Lowland in west-central Minnesota and the eastern Dakotas. This glacial lake drained into the Upper Mississippi via River Warren in the Minnesota Valley between about 11,000 and 9,500 years ago (Matsch, 1983) and marked the final episode of glacier-related discharge into the valley.

HOLOCENE

Following the last glacial down-cutting event the Mississippi River underwent a change in channel pattern from a braided pattern to an island braided pattern, which has continued through the Holocene. The Mississippi floodplain level has been at nearly the same elevation since about 11,000 years ago, but several shifts in channel position have occurred. During the early Holocene (before 6,000 B.P.) the main channel of the Mississippi was just east of the bluff line between Burlington and the village of Kingston, Iowa. Alluvial fans began to build out across the early Holocene floodplain along the bluff Line approximately 9,500 years ago. The Mississippi channel belt had shifted eastward to a position three to four miles east of the western bluff line in the vicinity of Kingston by 6,000 B.P. Alluvial fans continued to prograde, burying portions of the early Holocene channel belt and remained active through the middle Holocene. These alluvial fans stabilized during the late Holocene about 2,500 years ago.

Terraces in the Vicinity of Crapo Park

The Late Wisconsinan and Holocene alluvial fills of the Upper Mississippi Valley are defined by landform sediment assemblages (LSA) of Bettis et al. (1996). Each LSA is a set of discontinuous geologic units. Brief unit descriptions for LSA in the Burlington area are listed below:

Savanna (Savan)

The Savanna Terrace represents the highest terrace remnants in the Mississippi Valley without loess cover. The Savanna Terrace formed from approximately 17,000 to 12,000 years ago (Bettis and Hallberg, 1985). Near the Iowa/Minnesota border, the Savanna Terrace is approximately 20m above the Mississippi River floodplain. This decreases to near 10m south of Quincy, Illinois. The gradient of the terrace in the main valley is the highest of any Wisconsinan or Holocene surface. Very little of the Savanna Terrace remains intact today, partly due to extensive modification by human activities (urban development, agricultural activity, quarrying, etc.).

Kingston (Kings)

The Kingston Terrace consists of streamlined, sandy terrace remnants elevated 3-5m above the Mississippi floodplain. Terrace remnants are associated with a now-buried paleochannel system with channels several times broader than the historic Mississippi channel. The gradient is less than that of the Savanna Terrace, but greater than the Holocene floodplain gradient; therefore the height of the Kingston Terrace above the Mississippi floodplain decreases down valley. Younger Mississippi River abandoned channel areas typically separate the Kingston Terrace remnants from the valley wall.

Kingston Terrace deposits are greater than 10m thick and consist of valleytrain outwash deposited between about 12,000 and 10,400 years ago. Silty, loamy, and Superior Basin-source reddish brown silty clay deposits are present in some of the overflow channels as well as in all the deeper Mississippi paleochannels associated with the Kingston. The reddish brown silty clay sediments accumulated during the last Superior Basin overflow events into the Upper Mississippi Valley between 9,800 and 9,500 B.P. The sandy fluvial deposits of the Kingston Terrace are mantled with thin (usually less than 2m thick), eolian sand comprising sand sheets and low dunes. The Kingston Terrace is underlain by trough cross-bedded and planar-bedded sand and pebbly sand. These deposits are usually less pebbly than deposits associated with the Savanna Terrace.

Early to Middle Holocene Channel Belt (Emhol)

The Early to Middle Holocene Channel Belt encompasses low-relief, slightly undulating, poorly drained, linear to broadly arcuate surfaces on the Mississippi floodplain, which mark the location of Mississippi paleochannel positions and associated islands during the Early and Middle Holocene. High stage Mississippi floodwaters overtop portions of this LSA where unrestricted by artificial levees. North of the Quad Cities most of this LSA is flooded by pools of the lock and dam system. EMHOL is located on both sides of the floodplain and is most extensive in the wide valley reaches south of the Quad Cities. EMHOL is inset below the Savanna and Kingston Terrace LSA, can either cut or be cut out by the Yazoo meander belt LSA, and is buried by the Mississippi Levee LSA. The Late Holocene Channel Belt and Tributary Fan LSAs cut out the Early to Middle Holocene Channel Belt LSA.

The EMHOL deposits consist of a variable thickness of loamy, silty clay loam and clay loam overbank alluvium grading downward to sandy loam, sand, and pebbly sand in-channel deposits. The fine-grained deposits mantle most of the LSA and range in thickness from about 1.5 meters on swells to over 6 meters in abandoned channel areas. The oldest portions of the LSA are underlain by Superior-source reddish brown silty clay slackwater sediments that were deposited between 9,600 and 9,200 B.P. Buried soils (formed during periods of low Mississippi River flood frequency) are common in this LSA and many wetland areas are underlain by peat, muck or fine-grained lacustrine sediments that may contain well-preserved paleoenvironmental records (from pollen, plant macrofossils, insects, ostracods, fish, etc.). Deposits range in age from 10,400 to about 4,500 B.P. Thin younger deposits may overlap portions of this LSA.

Less Prominent Lsas in the Burlington Area

The Yazoo Meander Belt (YAZOO) consists of low-relief, undulating to slightly undulating, arcuate surfaces associated with tributary and anabranch stream channel belts on the Mississippi floodplain. Deposits consist of a complex mosaic of criss-crossing channels and associated scroll bars, natural levees, and abandoned channels (which may contain marshes and small oxbow lakes). Although no complete record is present at any one locality, these deposits span the Holocene.

The Late Holocene Channel Belt (LAHOL) encompasses low relief, slightly to moderately undulating, poorly drained, broadly arcuate surfaces where sloughs and abandoned channels are abundant on the Mississippi floodplain. LAHOL deposits consist of variable thicknesses of loamy, silty clay loam, and clay loam alluvium overlying sand and pebbly sand in-channel and sand ridge deposits. The fine-grained deposits range from 1-2.5 meters in thickness and mantle most of the LSA but are thin to absent on ridges. Deposits of this LSA accumulated between 4,500 B.P. and the Historic period.

The Island LSA (ISLAN) includes all landforms and deposits on historic islands in the Mississippi Valley. The ISLAN deposits consist of variable thicknesses of fine-grained alluvium overlying sandy and pebbly sand alluvium. Fine-grained deposits may be lacking on sandy ridges and from recently formed bars on the island margins. Below the Quad Cities, post-settlement alluvium (PSA) mantles all surfaces in this LSA, reaching thicknesses of two meters or more along the margins of the islands (thickness of the PSA is more variable above the Quad Cities ranging from >1m to a few cm). Deposits in the ISLAN PSA range from about 5,000 B.P. on large islands north of the Quad Cities to less than 3,500 B.P. on large islands south of the Quad Cities.

The Fan/Colluvial Slope LSA (FANCO) includes alluvial fans and colluvial slopes along valley margins. These surfaces are above the Mississippi River floodplain and bury the Savanna Terrace and Kingston Terrace LSAs. FANCO has interfingering relationships with EMHOL, YAZOO, and TRIFA LSAs. FANCO deposits are stratified silty, loamy, clayey, sandy, and pebbly sand alluvium derived from erosion in tributary valleys and from the valley wall. Thickness ranges from 3 to 15m and contain several upward-fining sequences with paleosols. FANCO deposits accumulated between 9,000 and 2,500 B.P.

Other LSAs in the Upper Mississippi River Valley not discussed in this description include the Gilead Terrace (GILEAD), Cuivre Terrace (CUIVRE), Mississippi Levee (LEVEE), Tributary Fan (TRIFA), Unknown Category (UNKNOWN), and Post-Settlement Alluvium (PSA) (Bettis et al., 1996).

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BEDROCK STRATIGRAPHY IN THE BURLINGTON AREA

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INTRODUCTION

The Mississippian System was historically proposed for the succession of strata exposed in the Mississippi River Valley between Burlington, Iowa, and St. Louis, Missouri. Therefore, the bedrock exposures in and around the City of Burlington take on special significance as they comprise part of the historic "body stratotype" on which the concept of the Mississippian System was defined and based. Until recently, the Mississippian has been primarily a North American chronostratigraphic label roughly synonymous with the Lower Carboniferous of the Old World. As recently approved by the Subcommission on Carboniferous Stratigraphy (in 1999) and ratified by the International Union of Geological Sciences and the International Commission on Stratigraphy (in 2000), the Carboniferous System has been officially subdivided into lower and upper subsystems, the Mississippian and Pennsylvanian, respectively. As such, the Mississippian now has meaning and application as a major chronostratigraphic subdivision of geologic time not only in North America, but as a globally defined subsystem. The bedrock strata at Burlington provide a significant historic reference for the internationally recognized Mississippian Subsystem. This GSI trip can be viewed as a sort of international geologic pilgrimage to the classic Mississippian succession in its type area.

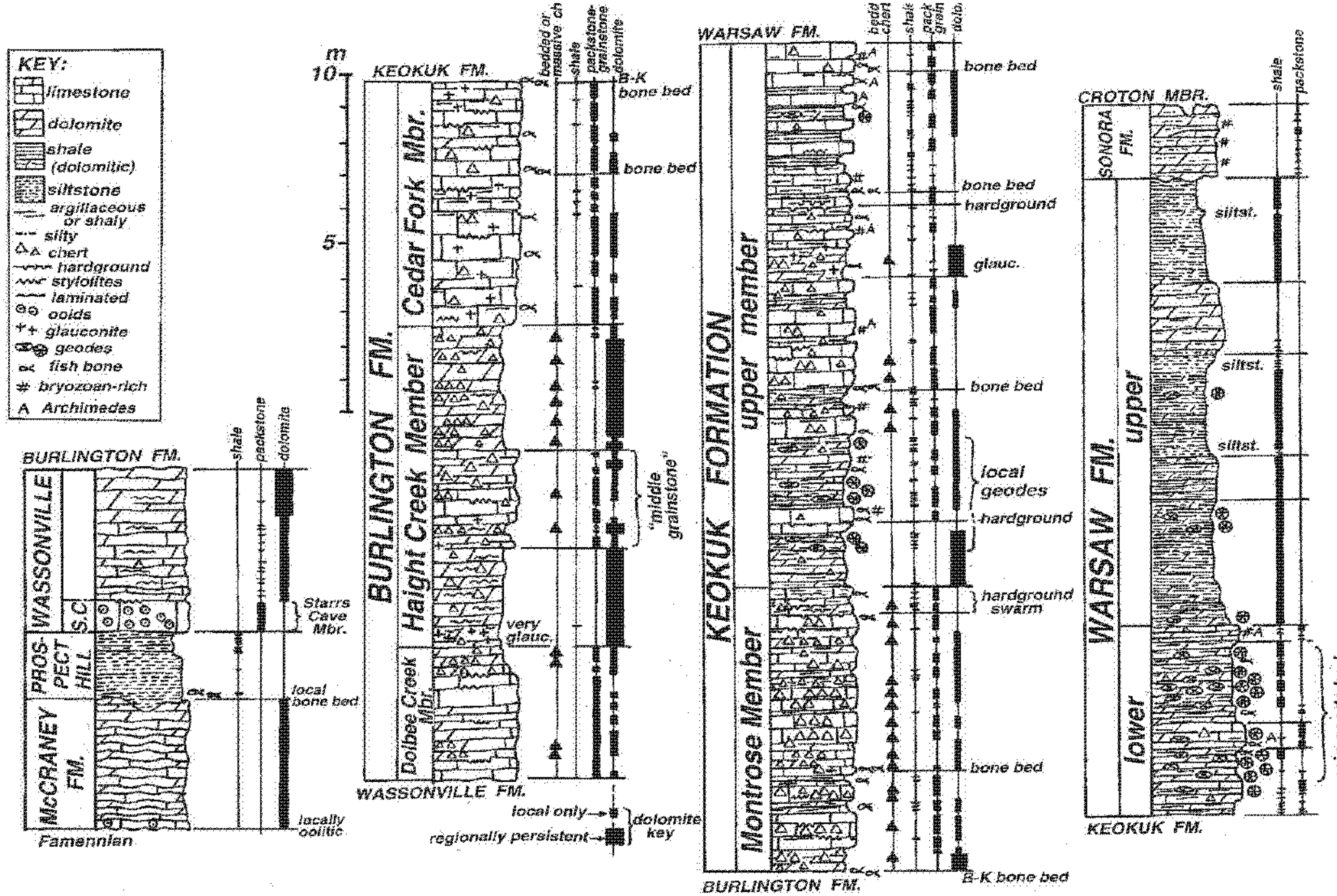
Bedrock strata are well exposed in the Burlington area at places along the Mississippi River bluffs, its tributary valleys, and in numerous abandoned and operating quarries. The exposed stratigraphic succession begins in the lower reaches of the valley walls in an interval of Upper Devonian shale and siltstone. Proceeding upward, the Devonian strata are capped by a picturesque and fascinating succession of Mississippian strata including limestone, dolomite, chert, and siltstone lithologies. The thick limestone and dolomite interval that caps the Mississippi River bluffs at Burlington comprises that type area of the Burlington Formation, world-renowned for its exceptional fossil faunas, especially of crinoids.

The reader is referred to a more comprehensive stratigraphic summary of Mississippian rocks in southeast Iowa given by Witzke et al. (1990) for further information. In addition, a valuable field guide to the stratigraphic succession in the Burlington area (and Starrs Cave Park in particular) is provided by Glenister et al. (1987). The general stratigraphic succession for southeast Iowa is shown on Figure 1, and several key stratigraphic sections (including two field trip stops) in the Burlington area are illustrated on Figure 2. An overview of the bedrock stratigraphy seen in the Burlington area is given below to provide some stratigraphic perspectives for the field trip participants.

DEVONIAN SHALE AND SILTSTONE STRATA

A succession of shale and siltstone strata begins at the level of the Mississippi River at Burlington and rises up the lower valley walls a short distance (locally varying between about 20 to 45 feet in thickness). The upper siltstone-dominated portion of this interval (about 20-25 ft thick at Burlington) has been generally referred to the English River Siltstone (beginning with Laudon, 1931), a formation whose name derives from exposures along the English River in Washington County, Iowa ("English river gritstone" of Bain, 1896). This siltstone was earlier called the "Chonopectus sandstone," named after a distinctive and abundant brachiopod (Chonopectus fischeri) found in these strata at Burlington. This siltstone interval is

Figure 1. General sub-St. Louis Mississippian stratigraphic succession for southeast Iowa. This is a composite section based on outcrop and subsurface sections measured in Des Moines, Lee, and VanBuren counties. Stratigraphic variations in dolomite content are reflected by the width of black bars along the right edge of each column.



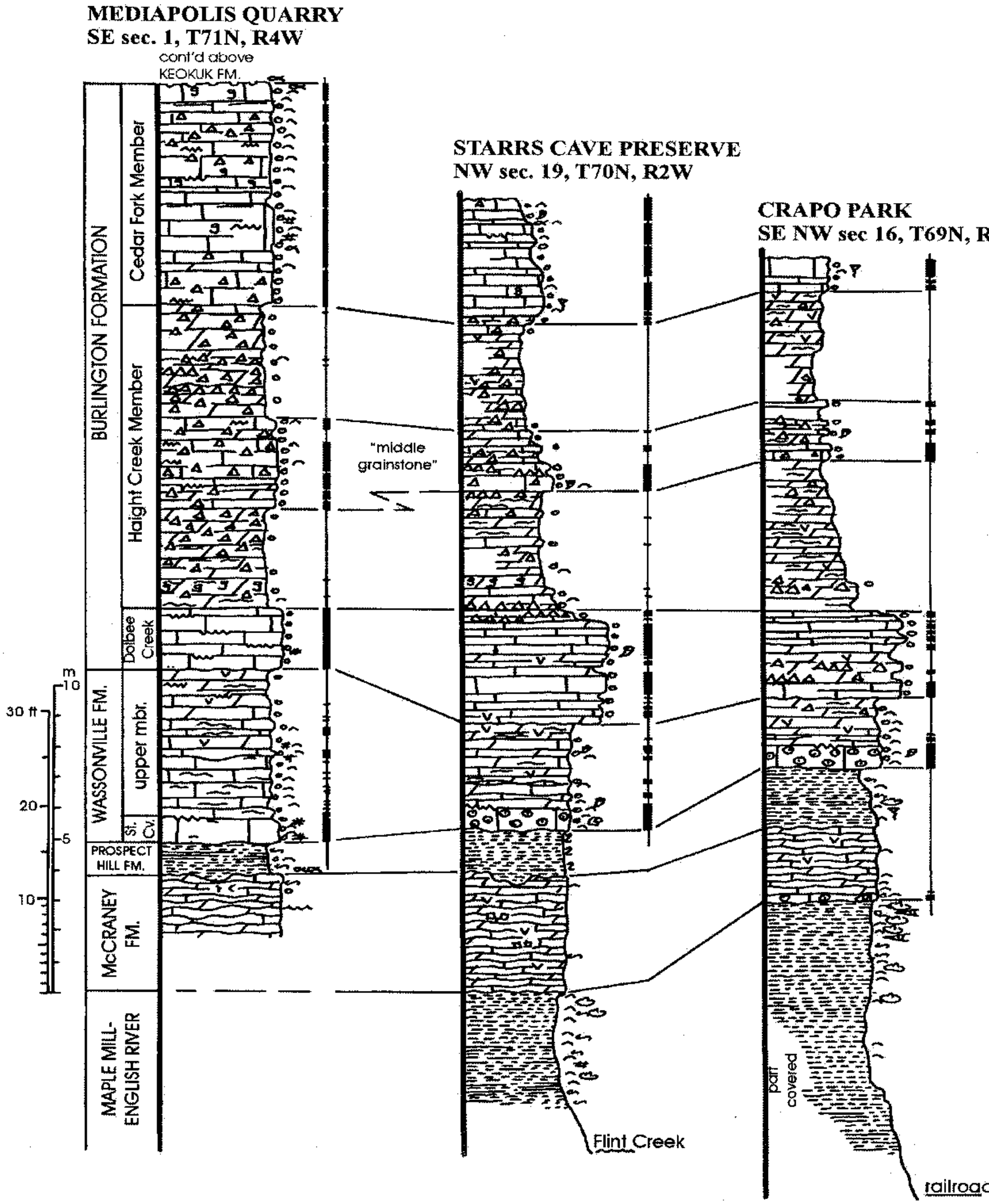


Figure 2. Graphic illustration of the stratigraphic succession and correlation of three reference sections in Des Moines County, Iowa. The Starrs Cave and Crapo Park sections are field trip stops (see more detailed section descriptions later in this guidebook). Black bars to the right of each stratigraphic mark the positions of skeletal (primarily crinoidal) packstone and grainstone units. Symbols primarily as in Figure 1. Additional fossil symbols on right edge of column include: crinoid debris (○), brachiopods (⌒), bryozoans (#), corals (∇), bivalves (oval form), gastropods (spiral form), cephalopods (horizontal conical form), fish (ichthys symbol), and burrows (⌣).

conformable and gradational with blue-gray shale formation below, and these shales have been traditionally assigned to the Maple Mill Shale across southeast Iowa (Laudon, 1931). The Maple Mill Shale also derives its names from exposures along the English River in Washington County (Bain, 1896).

It is generally accurate to correlate the lower shale-siltstone succession at Burlington with the Maple Mill-English River succession along the English River in Washington County, but some stratigraphic observations are pertinent. First, the English River Siltstone at its type locality, as originally defined by Bain (1896), included an upper siltstone interval that is now known to be of Mississippian age (and which correlates with the Prospect Hill Siltstone at Burlington; see Straka, 1968). Only the lower two-thirds of the siltstone interval at the English River type locality actually correlates with the Devonian siltstone at Burlington, and this interval now represents the re-defined type section of the English River Siltstone (Straka, 1968). Second, the English River Siltstone and Maple Mill Shale have traditionally been considered to be separate formations. Nevertheless, a distinctive and consistent separation of these two units is not always possible across southeast Iowa, and the contact is commonly gradational. An interval of interbedded shale and siltstone is common in many sections. In addition, regional subsurface stratigraphic investigations of the Upper Devonian shale-siltstone interval across southeast Iowa reveal that the English River Siltstone regionally shares lateral lithofacies relationships with the upper Maple Mill Shale. That is, the English River Siltstone is locally replaced by shale-dominated facies that are included in the Maple Mill Shale. As such, the lithostratigraphic separation of English River and Maple Mill strata does not mark a regionally correlatable stratigraphic datum, but merely reflects a complex siltstone-shale facies transition. Because of these facies relationships, the English River seems to be more logically included as an upper member within the larger and thicker shale-dominated formation.

Third, the Maple Mill Shale was originally defined and historically used as a lithostratigraphic label to include the entire succession of thick Upper Devonian shale found above the Cedar Valley Limestone in southeast Iowa. This broadly defined shale interval can and should be further subdivided into formation-level or member-level lithostratigraphic packages, as recommended by Dorheim, Koch, and Parker (1969), who grouped the Upper Devonian shale and siltstone succession into the "Yellow Spring Group." They restricted usage of the "Maple Mill" to the upper half of this succession below the capping English River Siltstone. Two additional Upper Devonian shale formations have been previously applied to the lower half of this succession in southeast Iowa, namely the Sweetland Creek Shale (or Lime Creek Shale) and Sheffield Shale. The Sweetland Creek Shale is an Upper Devonian shale interval named for a cutbank exposure in southeast Iowa (Muscatine County), and this unit has been shown to have stratigraphic utility as a formation across the Illinois Basin (Cluff et al., 1981). As an Iowa-defined term, the Sweetland Creek Shale should be recognized as a distinct lithostratigraphic unit in southeast Iowa. By contrast, the Sheffield Shale, a term introduced from north-central Iowa, has been used inappropriately in southeast Iowa (primarily on well logs), and further use of this term is discouraged in southeast Iowa. As used by Dorheim et al. (1969), the so-called "Sheffield" of southeast Iowa is neither a lithostratigraphic nor chronostratigraphic equivalent of the type Sheffield of north-central Iowa (see conodont correlations of Pavlicek, 1986, and Metzger, 1988). The term "Yellow Spring Group" seems largely synonymous with the "New Albany Shale Group" as presently used in Illinois (e.g., Cluff et al., 1981).

Fourth, the Upper Devonian shale interval exposed at Burlington and elsewhere in southeast Iowa (including Washington County) correlates with the shale succession in nearby areas of western Illinois and northeast Missouri. It is appropriate that previously named and correlable lithostratigraphic units in nearby Missouri and Illinois should be considered for possible use in southeast Iowa (in part to promote regional lithostratigraphic harmony). The Maple Mill-English River interval is lithostratigraphically indistinguishable from the Saverton Shale, a shale and siltstone unit whose name derives from the town of Saverton in northeast Missouri (Ralls County), and used in western Illinois. The full Upper Devonian shale succession in western Illinois and adjacent Missouri includes, in ascending order, the Sweetland Creek, Grassy Creek, and Saverton shales (Cluff et al., 1981). These same lithostratigraphic subdivisions can be recognized in southeast Iowa, and it may be appropriate to use them in Iowa to promote regional lithostratigraphic harmony with surrounding states.

The discussion above underscores a general confusion, both regionally and locally, for the lithostratigraphic nomenclature of the Upper Devonian shale succession in southeast Iowa. While a permanent solution is not presented here, some proposals are suggested. It is recommended that the English River Siltstone should be considered as the upper member of the Saverton Formation in southeast Iowa (and the Saverton introduced as a lithostratigraphic label in Iowa). If this approach is adopted, the Maple Mill could either be considered as the lower shale-dominated member of the Saverton Formation, or the Maple Mill could replace the Saverton as the formational label in Iowa. Further discussion and comments are welcome.

The lower shale and siltstone interval exposed at Burlington was once included as the lower part of the "Kinderhook" beds or group (beginning in 1861 with the James Hall era and continuing well into the 20th century, e.g., Laudon, 1931). The term derived from nearby Kinderhook, Pike County, Illinois, and the entire succession of "Kinderhook beds" (capped by the Burlington Limestone) was considered to be of Carboniferous (Mississippian) age. However, it was subsequently discovered that the lower shale-siltstone package at Burlington is, in fact, an Upper Devonian interval, not part of the Carboniferous at all. As such, these strata were removed from the "Kinderhook group," and the name Kinderhook was applied only to the overlying succession, above the English River Siltstone and below the Burlington Limestone. The Kinderhookian is now a chronostratigraphic label for the basal Series of the Mississippian System.

Most geologists and paleontologists working in the area now recognize the English River Siltstone as an Upper Devonian rock unit (not Kinderhookian). This age assignment is based on the recovery of Devonian conodonts from the English River Siltstone at Burlington (Cascade Station) and in the type area along the English River in Washington County (Collinson, 1961; Scott and Collinson, 1961; Straka, 1968). In addition, clymeniid ammonoids (Cyrtoclymenia strigata) have also been collected in the Burlington area that clearly indicate a Late Devonian age (late Famennian) age (Glenister et al., 1987). Nevertheless, Carter (1988, p. 11) reached the following conclusion about correlation of the rich brachiopod fauna from the English River Siltstone at Burlington: "the Glen Park of Missouri, . . . the Horton Creek . . . and lower Hannibal . . . of Illinois, and the English River Sandstone of southeastern Iowa are the same age and can be confidently correlated." Because the Glen Park, Horton Creek, and lower Hannibal are all Mississippian (lower Kinderhookian) units, Carter therefore included the English River Siltstone at Burlington within the Mississippian. The conodont and ammonoid biostratigraphy, however, clearly indicates that his correlations are in error. There is great similarity between the brachiopod faunas of the late Famennian (English River) and early Kinderhookian (Glen Park, Horton Creek, lower Hannibal) in the area, and many brachiopod species apparently ranged across the Devonian-Mississippian boundary unchanged.

The English River Siltstone at Burlington contains a rich and varied fauna, and their fossils are seen as well-preserved internal and external molds. Fossils are most abundant in the upper beds of the siltstone unit, and the lower beds are variably fossiliferous (commonly burrowed but lacking shelly fauna). The shelly fauna at Burlington is highly diverse, typically dominated by bivalves (clams) and brachiopods. About 25 species of brachiopods (Weller, 1900; Carter, 1988) and 32 species of bivalves (Weller, 1900) are recognized. In addition gastropods (21 species), cephalopods, scaphopods, conularids, and bryozoans are also noted.

BASAL MISSISSIPPIAN MCCRANEY FORMATION

The base of the Mississippian at Burlington is drawn at the base of the McCraney Formation, and the basal contact is slightly irregular with up to 3 to 10 cm of relief indicating an unconformity. The McCraney was named for exposures in western Illinois, and it is an unusual and highly distinctive rock unit in southeast Iowa and the Mississippi Valley area. "The McCraney is composed of alternating beds of sparsely fossiliferous, buff-colored sublithograpic limestone, and dark brown, coarser-grained unfossiliferous dolomite" (Person, 1976, p. 21). The alternation of light and dark lithologies imparts a "strikingly banded appearance" (Glenister et al., 1987), sometimes called "zebra-striping." The striped bands are early diagenetic features, but the exact origins of the peculiar wavy (to nodular) bedding and dramatic lithologic alternations are perplexing.

A thin basal limestone bed is locally seen at the base of the McCraney in the Burlington area (as at Crapo Park), and this bed is oolitic to skeletal (in part with abundant chonetid brachiopods, Rugosochonetes gregarius). Otherwise, the bulk of the McCraney is frustratingly unfossiliferous. However, chonetid brachiopods are locally sparse to common in the lower part, and scattered rhynchonellid brachiopods are occasionally seen in the upper part (the so-called "Paraphorhynchus zone"). The McCraney is about 8 to 13 feet thick in the Burlington area, but the formation reaches thicknesses to 65 feet in southeast Iowa.

The McCraney and overlying Prospect Hill Siltstone and Starrs Cave Oolite were lumped together by Laudon (1931) to comprise the "North Hill formation." North Hill is the historic name for the prominent bluff that occupies the northern part of the City of Burlington, immediately north of the downtown area (and centered near the North Hill School), and the type section of the "North Hill formation" is seen low in the bluff facing the Mississippi. These strata were subsequently elevated to group status, the North Hill Group, containing the McCraney, Prospect Hill, and Starrs Cave formations (Workman and Gillette, 1956). Lithologic and faunal similarities between the Starrs Cave and overlying Wassonville Formation led Collinson (1961, p. 107) to suggest that the Wassonville "should be included in the North Hill Group." We concur that the Starrs Cave-Wassonville interval should be united within the same lithostratigraphic grouping. However, if the North Hill Group includes the Mississippian succession from Prospect Hill through Wassonville, the group would encompass the entire Kinderhookian interval at Burlington. While we have no inherent problem with uniting these strata within a unified lithostratigraphic grouping, complex facies relationships between North Hill strata in the Burlington area and Kinderhookian facies to the northwest (in Iowa) and south (into western Illinois and northeast Missouri) make the North Hill label of limited geographic use. Although the North Hill Group may have limited application as a term in the Burlington area, the restricted utility of this lithostratigraphic grouping does not seem to warrant its elevation to group status.

PROSPECT HILL FORMATION

A distinctive siltstone interval above the McCraney at Burlington was named the Prospect Hill siltstone by Moore (1928), who regarded this unit as a member of the Hannibal (a shale and siltstone formation in northeast Missouri). Workman and Gillette (1956) separated the Prospect Hill from the Hannibal and elevated it to formational status. The name Prospect Hill derives from the major bluff that occupies the southeastern part of the City of Burlington (centered near the North Hill School), immediately south of the downtown area and north of Crapo Park. The exposures of the Prospect Hill Formation examined on this trip represent typical sections in the historic type area of the formation. The formation extends across much of Iowa and portions of Illinois.

The Prospect Hill Formation is dominated by siltstone in the Burlington area, slightly argillaceous with scattered shaley partings. The siltstones locally display horizontal laminations and low-angle cross stratification to hummocky bedforms. Vertical to horizontal burrow fabrics are locally prominent. Fossil molds are variably common to absent in individual sections, but some beds locally contain abundant fossil molds. The shelly fauna is very similar to that seen in the older English River siltstones, and the Prospect Hill fauna is generally dominated by bivalves and brachiopods. Gastropods, cephalopods, scaphopods, bryozoans, and crinoid debris are also noted.

As displayed in the Burlington area, the Prospect Hill Formation is a relatively thin interval only about 4 to 8 feet thick. The formation overlies a slightly eroded surface on the McCraney, locally with up to 16 inches of relief (as seen at Starrs Cave Preserve). The top of the Prospect Hill Formation also locally shows some minor erosional relief (to 2 inches) in the Burlington area, and it is probable that the formation is bounded above and below by unconformity surfaces. The formation locally displays concentrations of fish bone (bone bed) at its base (as at the Mediapolis Quarry), and its thickness varies dramatically across southeast Iowa (locally reaching thicknesses to 90 feet). Where the formation is thick, it generally includes significant shale facies with a capping siltstone interval. Southward relationships of the Prospect Hill and some part of the Hannibal Formation (shale and siltstone unit) in Missouri seems likely.

WASSONVILLE FORMATION

An interval of carbonate rock, including fossiliferous to oolitic limestone and dolomite, cherty in part, overlies the Prospect Hill Siltstone at Burlington. The basal part of this interval was named the Starrs Cave Formation by Workman and Gillette (1956); the type locality is located at Starrs Cave Preserve along Flint Creek a short distance north of Burlington (see field trip stop). The Starrs Cave is a relatively thin limestone unit that is characteristically a fossiliferous oolitic grainstone, although the interval is a sparsely oolitic to non-oolitic skeletal packstone to grainstone at some localities in southeast Iowa. This interval is generally only 1.5 to 5 feet in thickness in the Burlington area, but it thickens westward (to 15 ft) in southeast Iowa (Witzke et al., 1990). Limestones of the Starrs Cave are locally absent at some localities (especially in Washington County) where Wassonville dolomites directly overlie the Prospect Hill Siltstone. However, dolomitized oolitic strata at the base of the Wassonville in that area indicate that Starrs Cave equivalents are actually present (Straka, 1968).

The contact between the skeletal to oolitic Starrs Cave limestone and overlying dolomite strata is gradational and interbedded. The contained benthic faunas (especially the brachiopods) are identical in the Starrs Cave limestones and the overlying dolomite beds. The upper contact of the Starrs Cave is arbitrarily selected at the base of the lowest dolomite in the succession. As suggested by Witzke et al. (1990, p. 11), the gradational character of Starrs Cave and Wassonville dolomite strata indicates that the two units should be naturally grouped (and the contact not used to mark the top of a formation or the bounding top of the "North Hill Group"). They wrote: "Although the thin Starrs Cave interval has been accorded formational status and separated from overlying Wassonville strata in most previous reports, it may be desirable at some point to re-assign the Starrs Cave as a member of the Wassonville Formation." Since no serious objection has been expressed over this suggestion, we are here formally proposing that the Starrs Cave be considered the basal member of the Wassonville Formation, and not a separate formation by itself.

The Wassonville Formation is a dolomite dominated unit, but interbedded limestone and dolomitic limestone lithologies are present (especially in the lower part), and the basal portion is limestone (the Starrs Cave Member) at most localities. Wassonville strata locally display silicification fabrics and nodular chert bands, but these are irregular in their distribution. The dolomite beds commonly display obscure or faint irregular laminations. Thin interbedded fossiliferous limestones are seen as stringers or starved bedforms, commonly with abundant brachiopods (especially chonetids). The dolomite-dominated portion of the Wassonville Formation above the basal Starrs Cave Member represents the upper member of the formation. These upper strata have not been formally named as yet, and they are here informally termed the "upper member." A number of representative sections of this interval can be found in southeast Iowa, and good candidates for the type section of the "upper member" include the Mediapolis Quarry and West Chester Quarry (see Witzke et al., 1990, p. 13).

The upper contact of the Wassonville Formation with the overlying Burlington Formation in southeast Iowa is sharp, although the nature of this contact is a difficult one to understand in a regional context. Minor relief (to 4 inches) on this contact is locally seen in the Burlington area, although at many localities it appears roughly planar with no obvious erosional relief or evidence of subaerial exposure. At some localities the contact is marked by a prominent hardground surface (probably of submarine origin). Even though this contact does not appear to be deeply eroded, regional truncation of Wassonville strata is evident on regional scale. Progressive eastward and southward thinning of the Wassonville is seen across southeast Iowa which appears to bevel the upper member. The formation thins from 60 to 35 feet eastward across Keokuk and Washington counties. In the Burlington area, the Wassonville thins from 19 feet at the Mediapolis Quarry (north of Burlington) to only 7.4 feet at Crapo Park. Southward to the Keokuk area (as at the Hamilton Quarry) and adjoining areas of west-central Illinois, the entire Wassonville Formation becomes truncated, and the Burlington Formation directly overlies the Prospect Hill Siltstone.

What is the origin of this southeastward beveling of the Wassonville Formation? Is it simply subaerial erosional truncation along a major unconformity surface? If this is the case, the direction of beveling seems anomalous. The general shoreward direction during Mississippian deposition was to the northwest in Iowa (toward the Transcontinental Arch), and the Kinderhookian and lower Osagean succession in northern Iowa includes facies not seen in southeast Iowa, including peritidal carbonates, mudcracked exposure surfaces, and stromatolites. The presence of shallower-water deposition and the progradation of peritidal carbonates across northern Iowa clearly shows that shoreward areas lie to the northwest, not to the southeast. However, the shallower-water Kinderhookian-lower Osagean succession in northern Iowa is much thicker and more complete than that seen in the more offshore areas of southeastern Iowa. How can this be? Shouldn't the erosional beveling of Kinderhookian strata expand in a shoreward direction, not in an offshore direction? The southeastward truncation of Wassonville strata seems strangely perplexing.

The southeastward expanding hiatus that separates Kinderhookian strata from the overlying Burlington Formation in Iowa may conceivably be explained by one of two possible explanations. First, some structural upwarping across the shallow shelf may have temporarily disrupted the general deepening-and-shallowing trends across the seaway and reversed the direction of erosional beveling. Although we cannot categorically dismiss this suggestion, the complete absence of peritidal deposition in southeast Iowa (and the common occurrence of such facies in northern Iowa) seems to undermine this idea. Secondly and alternatively, the southeastward erosional beveling of Kinderhookian strata may have resulted from lower rates of sediment accumulation and increased erosional beveling in an offshore direction. This suggestion initially seems counter-intuitive. Although many details of regional Mississippian sedimentation need to be worked out, Witzke and Bunker (1996) proposed that the sub-Burlington discontinuity may actually be a broad submarine surface marked by widespread sediment starvation in offshore areas (of the "middle shelf"). The beveling of sub-Burlington strata may, therefore, represent submarine erosional planation (perhaps related to recurring storm current activity that episodically eroded and transported material from broad areas of the "middle shelf"). As we examine the Wassonville-Burlington contact on this field trip, it would be well to ponder the regional relationships and ramifications of this surface. A broader understanding of this disconformity surface may have far-reaching effects on our understanding of the nature of the stratigraphic record in cratonic areas.

BURLINGTON FORMATION

Owen (1852) described the "encrinital group of Burlington," and the term "Burlington limestone" was introduced by Hall (1857) and Hall and Whitney (1858) for the succession of crinoidal limestones exposed in the Mississippi River bluffs at Burlington, Iowa. These exposures at Burlington have long been famous for their rich paleontologic resources, especially the fantastic crinoid faunas (Wachsmuth and Springer, 1897) and to a lesser extent the brachiopods (Weller, 1914). We will examine some of the classic exposures in the type area of the formation for this field trip. The Burlington is presently used as a formational term over a broad area of the Midcontinent, from Iowa to Arkansas, and from Illinois to Kansas. The Burlington Formation is beautifully exposed not only in the Burlington area, but prominent exposures are also well displayed for long stretches along the Mississippi River bluffs farther downstream in Illinois and Missouri. As resurrected by Witzke et al. (1990), the Burlington Formation forms the lower part of the Augusta Group (named after the town of Augusta west of Burlington). The Burlington Formation marks the lower portion the Osagean Series in the Mississippi Valley area.

Although crinoidal limestones (packstones and grainstones) are an important and distinctive part of the Burlington Formation across its extent, thick intervals of dolomite subdivide the succession into several distinct stratigraphic units. Harris and Parker (1964) subdivided the Burlington Formation in southeast Iowa into three members, in ascending order: the Dolbee Creek Member (dominated by crinoidal limestones), the Haight Creek Member (dominated by cherty dolomite strata), and the Cedar Fork Member (dominated by cherty crinoidal limestone). The Burlington Formation averages about 65 feet in thickness in the Burlington area (full thickness where capped by the overlying Keokuk Formation). However, the top of the Mississippi River bluffs in the City of Burlington generally occupies a position within the Cedar Fork Member, and the uppermost part of the formation is erosionally missing.

The Dolbee Creek Member varies between about 6 and 13 feet in thickness in the Burlington area, where it is characterized by a stacked succession of crinoidal packstones and grainstones. The crinoidal limestone beds may be graded (coarsest crinoid grains at the base), and many individual beds display lenses, stringers, and starved megaripple bedforms of fine to coarse crinoid debris. Such crinoidal beds commonly amalgamate into thicker intervals of crinoidal grainstone. The crinoidal beds are interbedded in a complex manner with less fossiliferous mudstone and wackestone lithologies, usually seen as dolomite and dolomitic limestone interbeds. Some of the dolomite beds are locally cherty. The dolomite interbeds are replaced by crinoidal limestones over short lateral distances, and in some sections (as at the Mediapolis Quarry) dolomite interbeds are entirely absent. Unlike the underlying Wassonville Formation, the Dolbee Creek Member generally thins westward into Washington County but thickens southward in the Mississippi Valley. Near St. Louis, Missouri, the lower Burlington crinoidal limestones are further underlain by an additional basal Osagean formation (Fern Glen Fm.) not seen at Burlington.

The Dolbee Creek Member is overlain by the dolomite-dominated Haight Creek Member (30-33 feet thick in the Burlington area). These dolomite strata are cherty to very cherty in part, but in the Burlington area these strata are commonly poorly exposed along the bluff slopes. The dolomites are generally sparingly fossiliferous, although molds of crinoid debris, brachiopods, and other fossils are seen. Many of the dolomites display faint laminations, possibly relict hummocky stratification. Prominent large chert nodules and bedded cherts (up to 30 cm thick) are common in the interval, and these whitish cherts were widely used by aboriginal peoples for thousands of years because of their exceptional quality for flint knapping. A distinctive glauconitic unit (a greenish-colored bed) occurs at or near the base of the Haight Creek Member throughout its extent in Iowa. This glauconitic bed forms a major stratigraphic marker within the Burlington Formation (as first recognized by Harris and Parker, 1964). An interval of more resistant limestone strata (crinoidal packstones and grainstones similar to those seen in the Dolbee Creek and Cedar Fork members) is found in the middle part of the Haight Creek Member in the Burlington area and throughout most of southeast Iowa. This crinoidal limestone interval has been termed the "middle grainstone" unit by Witzke et al. (1990).

The Cedar Fork Member comprises the upper part of the Burlington Formation, and these strata are dominated by crinoidal limestones (packstones and grainstones) similar in many respects to those seen in the Dolbee Creek and "middle grainstone" interval. However, chert nodules are generally more common in the Cedar Fork Member than seen in the Dolbee Creek, and some of the crinoidal limestones of the Cedar Fork are glauconitic to varying degrees (the glauconite is seen as small green pellets <1 mm in size). Minor dolomite and dolomitic limestone interbeds are locally present within the member. Although brachiopods occur in varying abundance within all crinoidal limestone units of the Burlington Formation, some of the Cedar Fork limestones display prominent large brachiopods (commonly silicified), especially the very large spiriferid known as Spirifer grimesi. Likewise, any of the crinoidal limestones of the Burlington Formation can potentially produce articulated crinoid cups, but we have found that crinoid cups are most commonly encountered within the Cedar Fork Member. Concentrations of fish bone (especially bradyodontid shark teeth) can be found on some bedding surfaces within the Cedar Fork Member, and bones are particularly abundant and prominent at the top of the member (the widespread Burlington-Keokuk bone bed).

POST-BURLINGTON MISSISSIPPIAN STRATA IN THE AREA

Although the bluff exposures at Burlington range no higher than the Cedar Fork Member of the Burlington Formation, higher Mississippian strata can be seen in the area and elsewhere in southeast Iowa (see Fig. 1). The Burlington Formation is overlain by the Keokuk Formation in southeast Iowa and adjacent areas of Illinois and Missouri, and strata of the lower Keokuk are locally preserved in the greater Burlington area. Good exposures of Keokuk strata can be seen in Des Moines County at several places (e.g., Mediapolis Quarry, Augusta quarries). The Keokuk Formation shows many lithologic similarities with the Burlington Formation, being characterized by a succession of crinoidal limestones (packstones-grainstones) and cherty dolomites. The Keokuk Formation usually can be distinguished from the Burlington by its more argillaceous to shaley character and by the generally darker color (brownish-colored) of the crinoidal and skeletal limestones.

The Keokuk Formation is capped by the Warsaw Formation in southeast Iowa, and the lower part of the Warsaw includes the world-famous "geode beds." Beautiful quartz geodes, Iowa's state rock, are abundant in dolomite strata of the lower Warsaw Formation, although geodes are also locally seen in portions of the Keokuk and upper Warsaw as well (see Fig. 1). Upper Warsaw strata are dominated by shale and shaley dolomite lithologies in southeast Iowa. Burlington, Keokuk, and Warsaw strata are lumped together within the Augusta Group (Witzke et al., 1990).

A prominent regional erosional unconformity developed across Iowa following deposition of the Augusta Group, and deep erosional incision is documented in southeast Iowa (locally as deep as the lower Keokuk Formation in southeast Iowa). The scope and extent of this erosional episode indicates that the seaway completely withdrew from Iowa, and the landscape was subjected to significant subaerial and fluvial erosion. Above this erosional surface, younger Mississippian strata were deposited when the seaway once again returned to Iowa. These include the "St. Louis" and Pella formations (Witzke et al., 1990). Following the subsequent withdrawal of the Mississippian seaway from Iowa, a prolonged episode of erosion ensued. Above the Mississippian erosional surface in southeast Iowa, Pennsylvanian deposits are seen locally which include channel-filling sandstones, mudstones, coals, and thin limestones.

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PRE-WISCONSINAN STRATIGRAPHY IN SOUTHEAST IOWA

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INTRODUCTION

Illinoian ice advanced into Iowa from the northeast across Illinois and only reached the most southeastern portion of Iowa. Therefore, deposits in Iowa are limited. All of the Pre-Illinoian till units identified in east-central Iowa are present in the area of the fieldtrip; however, not all of these units are present at any one locality (either outcrop or core). We will be able to look at the Illinoian age Kellerville Till Member of the Glasford Formation and the Pre-Illinoian age Hickory Hills Member of the Wolf Creek Formation. Although the other till units will not be seen on this trip, they will be described for reference.

ILLINOIAN

Historical Studies

The Illinoian glacial deposits in southeast Iowa were first studied by Leverett (1898a, 1899). Early studies included detailed observations of the Pleistocene deposits of the "Illinoian Lobe" and led to the conclusion that the ice had traveled into Iowa from the northeast across Illinois. Leverett first used the name Illinoian stage to include both the interval of glaciation and the drift sheet. Leverett (1898a, 1898b, 1899) also identified the upper and lower boundaries as being marked by weathering zones, which he termed the Sangamon and Yarmouth Soils.

The original concept of the Illinoian stage defined by Leverett (1899) has been changed very little by subsequent researchers. The most significant change was the subdivision into three substages based on end moraine positions and mineralogy (Willman et al., 1963; Frye et al., 1964; Willman and Frye, 1970). These time-stratigraphic units were originally termed (oldest to youngest) the Payson, Jacksonville, and Buffalo Hart substages. The rock-stratigraphic concepts by Willman and Frye in the 1960's for the Quaternary were formalized in 1970 with the naming of several till members of the Glasford Formation. (Lineback, 1979)

Work during the 1950's and 1960's centered on characterizing the mineralogy and petrography. Multiple till units were identified and related to the substages of the Illinoian glacial. Leverett's Illinoian till was renamed by Leighton and Willman (1950) as the Payson substage, and later modified by Willman et al. (1963) to include the Petersburg Silt. Frye et. al (1964) suggested that the terms Mendon Till and Payson till be abandoned due to a lack of Illinoian age tills as far west as had been previously mapped. Instead, the name Liman was proposed for the earliest substages of the Illinoian and encompassing the time of deposition of the Petersburg Silt, the Mendon Till, and other Illinoian deposits stratigraphically below the Jacksonville Till.

These Pleistocene deposits and stratigraphy of Illinois were more formally classified by Willman and Frye in 1970, and the earliest Illinoian age till was named the Kellerville Till Member of the Glasford Formation. A formal stratigraphic nomenclature for Iowa was later defined by Hallberg (1980). The Kellerville Till Member of the Glasford Formation was described from roadcut exposures in western Illinois (Willman and Frye, 1970). The type section is located in southeastern Adams County, Illinois, approximately 100 km south of Burlington, Iowa. The Kellerville Till Member replaces the terms Mendon Till (Frye et al., 1964; Frye et al., 1969) and Payson Till (Leighton and Willman, 1950; Wanless, 1957).

Lineback (1979) later divided the Kellerville into two members, the upper (unnamed Till A) and the lower. However, data presented by Wickham (1980) does not provide enough evidence to support the subdivision of the Kellerville Till into a lower part and an upper part. The study suggests instead that unnamed till member A is a lateral variation of the type Kellerville Till Member, as unnamed till member A was not found in superposition with the lower part of the Kellerville Till.

Source Area

Unlike the other tills throughout Iowa, the Illinoian is believed to have a northeastern source area. Based on the eastern-derived erratics and the prominent west-facing terminal moraines, the ice moved from the east through Illinois and into Iowa and left drift widely exposed in Illinois, Indiana, and Ohio (Leverett, 1898a, 1899).

Studies have determined that the Illinoian till was deposited by the Lake Michigan Lobe, which advanced across western Illinois from the northeast and into Iowa (Leverett, 1899; Wickham, 1980). The Lake Michigan Lobe incorporated Paleozoic bedrock from the Lake Michigan Basin, which is reflected in both the mineralogy of the matrix and clasts of the Illinoian deposits (Lineback, 1980; Wickham, 1980). The northeastern source area for the Illinoian age tills is also evidenced by till fabrics and glacial landform orientations (Lineback, 1979). Provenance differences between the Illinoian and Pre-Illinoian tills (which moved through Iowa from N-NW) create identifiable distinguishing characteristics, both physical and mineralogical. Specifically, the Kellerville Till Member is distinguished from the Pre-Illinoian tills by the relatively high illite content, high dolomite content, and the abundance of Pennsylvanian lithologies in the very coarse sand through cobble size particles. The Illinoian formations are correlated using physical stratigraphy, pebble lithology, and quantitative values of clay mineralogy, particle-size distribution, matrix carbonates, and sand-fraction lithology (Hallberg et al., 1980)

Distribution and Thickness of the Kellerville Till Member

Illinoian ice only reached Iowa in the most southeastern portion of the state. This boundary was originally defined by Leverett (1898a) and has only been slightly modified with time (Kay and Graham, 1943; Ruhe, 1969). The distribution of the Illinoian age deposits in southeast Iowa is shown in Figure ?????

The Illinoian deposits in southeast Iowa extend along the western edge of the Mississippi River from just south of Fort Madison northward to near the mouth of the Wapsipinicon River at the boundary between Scott and Clinton Counties (Leverett, 1898a, Kay and Graham, 1943; Ruhe, 1969). The distance west from the Mississippi River varies ranging from approximately 4 miles near Muscatine to 20 miles north of Burlington. Illinoian deposits have been identified in Lee (NE ¼), Des Moines (all but NW corner), Henry (only SE corner), Louisa (eastern 2/3), Muscatine (all but NW ¼), and Scott Counties (southern 2/3).

The superglacial facies varies in thickness from a few feet to 93 feet (28.4m) at the terminal ridge of the Kellerville at Yarmouth (Hallberg et al., 1980). The thickest section of Kellerville Till in Iowa is located at the Yarmouth core site near the western terminus; however, the Illinoian materials in the core are entirely made up of the superglacial facies (Hallberg et al., 1980). Within a few miles of the Mississippi River at the Nelson Quarry Section, 77 feet (23.5m) of the basal till facies is present (Hallberg et al., 1980). Therefore, in areas where both the superglacial and subglacial till facies are present, the total thickness could exceed 93 feet. The thickness throughout most of western Illinois ranges from less than 1m to 25m thick, but estimates indicate that it may be up to 50m thick in deep bedrock valleys (Wickham, 1980).

PRE-WISCONSINAN STRATIGRAPHY IN SOUTHEAST IOWA

The materials lying below the Wisconsinan loess in southeastern Iowa are the Illinoian age Glasford Formation and the Wolf Creek and Alburnett Formations of the Pre-Illinoian (youngest to oldest). These formations are not all present at any one individual section or core, but are all found at some locality in southeastern Iowa.

The basic stratigraphy of southeast Iowa consists of the following:

- Wisconsinan Loess
- Sangamon and Late-Sangamon Paleosols
- Glasford Formation
  - Kellerville Till Member
    - Superglacial Facies
    - Subglacial/Basal Till Facies
- Yarmouth Paleosol
- Wolf Creek Formation
  - Hickory Hills Till Member
  - Dysart Paleosol
  - Aurora Till Member
  - Franklin Paleosol
  - Winthrop Till Member
  - Westburg Paleosol
- Alburnett Formation
  - Undifferentiated Members

The Pre-Illinoian deposits (Alburnett and Wolf Creek Formations) of southeast Iowa have the same general characteristics as described in east-central Iowa. As seen in other areas, the Wolf Creek and Alburnett Formations represent basal tills (uniform, dense, overconsolidated) that can be separated based on their clay mineralogy. The Alburnett Formation represents the oldest identified glacial deposits in the area. In other areas of east-central Iowa, the Alburnett consists of several undifferentiated members, but only one Alburnett Formation till has been recognized at any particular site. The Wolf Creek Formation consists of three members (youngest to oldest): Hickory Hills, Aurora, and Winthrop Members. These deposits show essentially the same stratigraphy and characteristics as elsewhere in Iowa. The Kellerville Till Member and associated sediments of the Glasford Formation are the only Illinoian age materials identified in the area. More formal descriptions are given in the following section.

TILL CHARACTERISTICS

Distinction between Illinoian and Pre-Illinoian Tills

Illinoian and Pre-Illinoian till units are distinguished from each other based on matrix carbonate data, clay mineralogy, and sand-fraction lithology. The Kellerville is an eastern source till from the Lake Michigan Lobe and has contrasting mineralogy with the Pre-Illinoian tills in the area. The Illinoian tills contain more illite than the Pre-Illinoian tills which entered Illinois from the northwest. Illinoian tills contain two to four times as much dolomite as calcite, whereas the Pre-Illinoian tills range from having more calcite than dolomite to less than twice as much dolomite (Lineback, 1979). The abundance of

Pennsylvanian rock fragments in the sand-size through pebble and cobble fractions is also evidence for an eastern source area (Hallberg et al., 1980).

Glasford Formation- Kellerville Member

The Kellerville Till Member of the Glasford Formation is the oldest of the Illinoian age tills. The Kellerville is separated into two till facies (a subglacial or basal till facies and a superglacial facies) based on stratigraphic position, sedimentological properties, and the consistency-density-consolidation properties (Hallberg et al., 1980; Wickham, 1980; Lineback, 1979). The basal till is a firm, dense, overconsolidated till with rather uniform texture. In contrast, the superglacial facies contains a wide variety of sediments and is highly variable in both texture and density. The superglacial facies includes till, diamicton (reworked till such as superglacial debris flows), sorted fluvial and lacustrine sediments, and peat beds. Deposits may be interbedded or occur as a contorted melange of sediments.

The superglacial and subglacial facies vary widely in texture, but are very similar in mineralogy, especially the clay abundance and the sand-fraction lithology. The clays are characterized by 46% expandables, 34% illite, and 20% kaolinite plus chlorite. Additional clay mineral characteristics (including a high illite to kaolinite plus chlorite ratio, moderate amounts of expandables, and the frequent occurrence of identifiable chlorite peaks) are used to distinguish the Kellerville from other units in the area. Clay mineral data from the Kellerville Member are more variable (wider range) than for other tills (Hallberg et al., 1980; Lineback, 1979).

One of the most distinguishing characteristics of the Kellerville Member is likely the high dolomite content in the matrix carbonates. The Kellerville has a much lower C/D (calcite to dolomite) ratio (less than 0.40) than the Pre-Illinoian deposits- Wolf Creek and Alburnett Formations (95% of which all have C/D ratios greater than 0.40). The Kellerville also exhibits a particularly high total sedimentary grain content in the very coarse sand fraction and an abundance of coal and black shale fragments in the sand fraction. The abundance of Pennsylvanian lithologies in the pebble fraction is also an important characteristic and often distinguishes the Kellerville in the field (Hallberg et al., 1980).

Wolf Creek Formation

The three members of the Wolf Creek Formation (Winthrop, Aurora, and Hickory Hills) consist of basal tills and intertill stratified sediments. The members are separated by soil stratigraphic units. The type areas for the Wolf Creek Formation and associated members are in east-central Iowa, but the units in southeast Iowa show the same general characteristics. The Winthrop Till Member has only been identified in a few localities in southeast Iowa. The Aurora and Hickory Hills Till Members are widespread throughout the study area.

The upper boundary of the Wolf Creek Formation is marked by the unconformable contact with Illinoian age deposits of the Glasford Formation. The Wolf Creek is underlain by either the Alburnett Formation or Paleozoic bedrock. The Yarmouth Paleosol is formed in the top of the Wolf Creek Formation. Beyond the reaches of the Illinoian deposits, the Glasford Formation Yarmouth-Sangamon soil is overlain by the Wisconsin loess. The individual till members may be directly overlain by each other or be separated by undifferentiated sediments, glaciofluvial deposits, or paleosols.

The Wolf Creek Formation is distinguished from the Alburnett Formation based primarily on clay mineral composition. The individual members are differentiated by grain-size variations. The Wolf Creek Formation averages 50-60% expandable clays (slightly lower in the southeastern portion of the state), 16-19% illite, and 22-24% kaolinite plus chlorite (Hallberg et al., 1980). The texture is typically loam, with the Winthrop Member ranging to light clay loam. The three members are differentiated based on particle size and matrix carbonate data. The Hickory Hills has relatively more sand, and the Aurora and Winthrop are relatively silty. The Aurora has a higher clay content than the Winthrop. Average clay, silt, and sand percentages are listed below (Hallberg et al., 1980):

Member	Clay %	Silt %	Sand %
Hickory Hills (n=87)	21.6±1.7	32.9±2.4	45.5±2.3
Aurora (n=41)	20.5±2.2	41.6±3.4	38.0±3.5
Winthrop (n=21)	27.6±1.9	42.0±2.3	30.4±1.9

Texturally the Aurora Till Member is very similar to the Kellerville, but mineralogically (both clay and matrix carbonate) they are very different. Also, in the southeastern portion of the state, 2% of the Aurora Till Member sand-fraction samples show traces of coal. The Kellerville Till Member also shows traces of coal and Pennsylvanian lithologies, but in much greater abundance than that of the Aurora Till Member. (Hallberg et al., 1980) In the area of the Illinoian deposits, the Hickory Hills Till Member is always found below the Kellerville Till Member and is the unit in which the Yarmouth Paleosol is formed. Beyond the limits of the Illinoian deposits, the Yarmouth-Sangamon or Late Sangamon Paleosol is formed in the Hickory Hills Till Member. Throughout the study area the Hickory Hills Till Member is typically very uniform in properties, both vertically and laterally, and may contain some block inclusions of substrate materials in its lowermost portions. (Hallberg et al., 1980)

Alburnett Formation- Undifferentiated Members

The Alburnett Formation is composed of multiple till units, which are considered "undifferentiated", and a variety of fluvial deposits. Minor paleosols may be seen within the deposits also. Throughout eastern Iowa, these deposits fill and bury the deep bedrock channels. The properties for the type areas are described in detail in Hallberg (1980). The clay mineralogy is very similar to that in the type areas and the particle size is also similar. The Alburnett Formation in southeast Iowa consists of 18.7% clay, 36.8% silt, and 44.4% sand (Hallberg et al., 1980). The Alburnett Formation is defined by its stratigraphic position and distinctive clay mineralogy. In comparison with the Wolf Creek Formation, the Alburnett tills have significantly lower percentages of expandable clay minerals and higher kaolinite plus chlorite. The Alburnett Formation contains 44% expandables, 24% illite, and 32% kaolinte plus chlorite (Hallberg et al., 1980). The Alburnett Formation tills have not been widely recognized in south-eastern Iowa, but a limited number of deep core holes have been drilled in the region. Both core holes drilled to bedrock (Yarmouth Core and Mediapolis-1) encountered the Alburnett Formation. Only one Alburnett Till was recognized in each hole, with a maximum thickness of 19 feet. The till was underlain directly by Mississippian bedrock with some minor inclusions of sand and gravel toward the base of the unit. The Alburnett was overlain directly by the Aurora Till Member of the Wolf Creek Formation. In outcrop, the Alburnett tills have only been identified in exposures near the bluffs of the Mississippi River in Des Moines and Lee counties. In these cases, the lower contact is not exposed and the top of the unit is overlain directly by the Wolf Creek Formation. (Hallberg et al., 1980).

STOP DESCRIPTION

At the last stop of the day (shown on Figure 1) we will look at the Illinoian age Kellerville Till Member and the Pre-Illinoian age Hickory Hills Till Member. This section was previously described (Hallberg, 1980) and the stratigraphic units exposed at the site are listed below:

This fieldtrip stop will revisit an area identified as the Pleasant Grove Section (29-PG-21). We will look at a stream bank exposure approximately 4 miles north of Danville along Flint Creek in the Pleasant Grove Quadrangle. This site is near a road cut exposure visited on previous investigations- listed as Stop 4 from the 27th Annual Midwest Friends of the Pleistocene (1980) and site 16M in Des Moines County from Iowa Geological Survey Technical Information Series Number 11: Illinoian and Pre-Illinoian

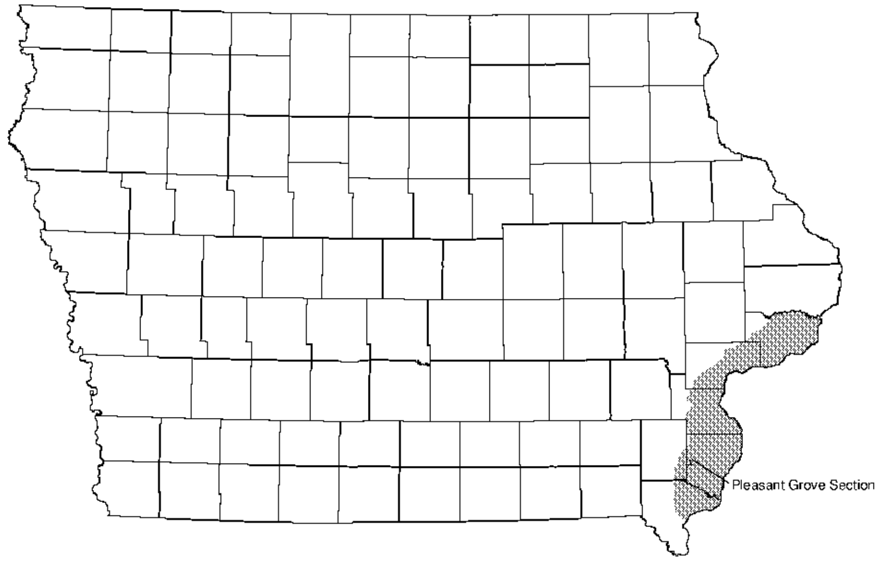

Figure 1: Shaded area shows the distribution of Illinoian tills.

Stratigraphy of Southeast Iowa and Adjacent Illinois (Hallberg, 1980). The site is located along the west side of highway X-31 in Des Moines County, Iowa (NE ¼, of the SE ¼, of the SE ¼, of the SE ¼, of Section 21, T71N, R4W).

The earlier section describes a site with Illinoian age Kellerville basal till sitting directly on top of Hickory Hills Member Pre-Illinoian till. A site visit prior to the trip identified a sand and gravel unit between the two tills. Although a detailed description of the current section has not been completed, these deposits are likely proglacial materials.

The previous section description (Hallberg et al., 1980) is as follows:

Depth feet (meters)	Horizon/ Zone	Description
GLASFORD FORMATION- Kellerville Till Member, subglacial facies, basal till.		
0-2.0 (0-0.6)	OL	Yellowish-brown (10YR 5/6), loam till; texturally uniform; firm; abundant coal, black shale, siderite concretions (Pennsylvanian lithologies in pebble fraction).
2.0-7.9 (0.6-2.4)	OU	As above, gray mottles increase with depth, abrupt lower contact.
WOLF CREEK FORMATION- Hickory Hills Till Member.		
7.9-9.4 (2.4-2.9)	OL	Strong brown (7.5YR 5/6) loam till; some iron oxide cement; no Pennsylvanian lithologies, very firm; maximum depth of leaching 1.5 feet (0.5m), but in place no leaching evident at contact.
9.4-10.4 (2.9-3.2)	OU	Strong brown (7.5YR 5/6) loam till.
10.4-10.9 (3.2-3.3)	OU2	As above wit habundant secondary carbonate concretions; color grading to yellowish brown (10YR 5/6), or dark yellowish brown (10YR 4/6).
10.9-18.7 (3.3-5.7)	OJU	Yellowish brown to dark yellowish brown loam till; some joints with iron-oxide stains; gray mottles increase with depth.

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FIELD TRIP STOPS

Field Trip Stop 1

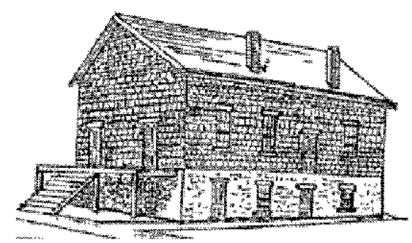
CRAPO PARK

INTRODUCTION

Ray Anderson

City of Burlington

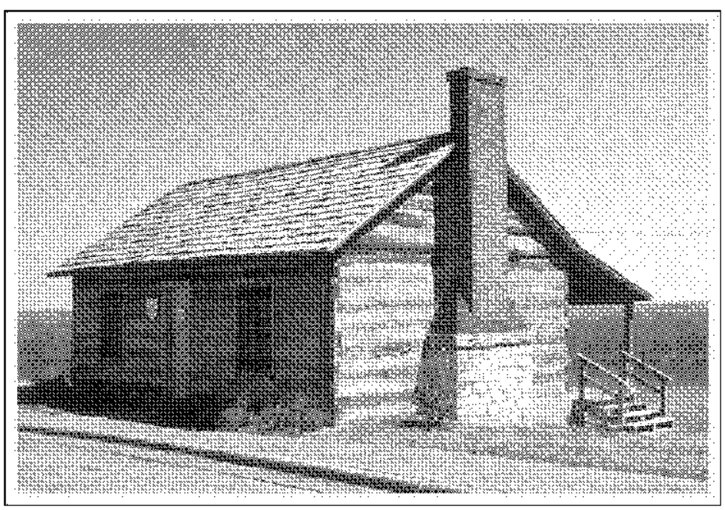
Located on the banks of the mighty Mississippi River, Burlington, Iowa, is the 17th largest city in Iowa and is home to 26,829 individuals who learn, work, and play in this city of many hills. Originally dubbed "Catfish Bend," the city has been a hub of commerce for the surrounding area. Burlington was the first capitol of the Iowa Territory from 1838 to 1840, and the second capitol of the Wisconsin Territory prior to that, 1837 to 1838. Although the historic Territorial Capitol building (shown to the right) no longer exists, a historical marker may be found at its site on Third and Columbia Streets. Burlington currently serves as the County Seat of Des Moines County



Sketch of Wisconsin Territorial Capitol Building

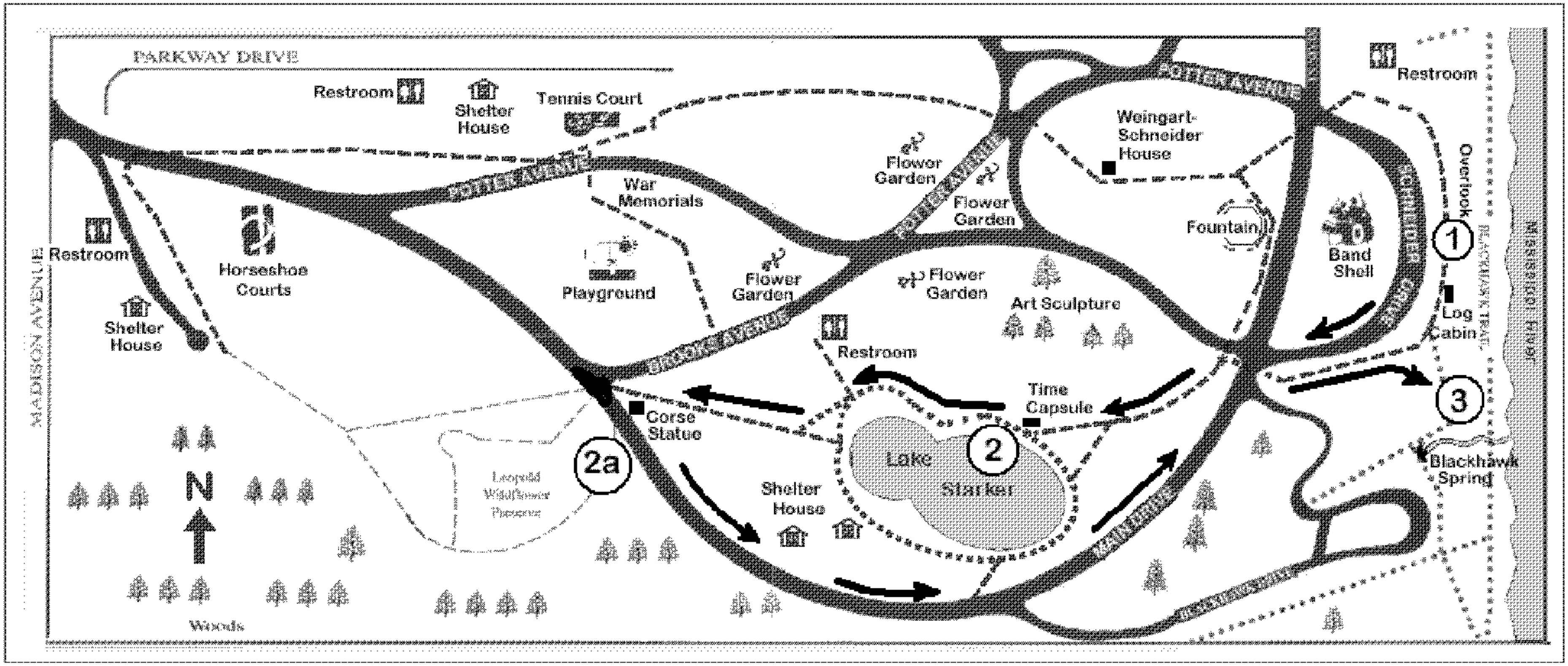
Crapo Park

Established in 1895, Crapo Park was named for Philip M. Crapo, a local businessman who was the leading force in the obtaining the funding and land for the park. Considered a Burlington pioneer, Philip Crapo came from an successful family that included an uncle Henry Howland Crapo) who was elected to two terms as Governor of Michigan and held numerous other offices during his lifetime, and a cousin, William Crapo Durant, who founded the Buick Company and General Motors and was the owner of the Chevrolet Motor Company. The 85-acre park was designed by Earnshaw and Punshon, a Cincinnati, Ohio, landscape engineering firm and was completed in the early Spring of 1896, in time for Iowa's semi-centennial celebration which was held in the park that October.



Hawkeye Native Cabin Museum at Crapo Park

One of the first sites that we observe when driving into Crapo Park is the Hawkeye Native Cabin. The cabin, presumably originally constructed by early settlers, was moved into the park in the early 1900s and was maintained by an organization called the Hawkeye Natives. Control of the cabin was eventually given to the Des Moines County Historical Society who now operate the building as a unique museum, featuring pioneer-era furniture and tools.



Map of Crapo Park, Burlington, Iowa

Crapo Park features excellent bluff exposures of several Mississippian units. We will observe these rocks as we take the ¼ mile hike along the Blackhawk Trail. Along the route we will see Blackhawk Spring. Although no Native American artifacts have been found around the spring, legends suggest that the area was considered a neutral area by the often-hostile area tribes. They would frequent the area to collect flint from which to construct points and tools.

Near the field trip gathering point, the Pike Memorial, a granite bolder, stands in tribute to Lt. Zebulon Pike, who stopped here while he was searching for defensible positions for forts in the new Louisiana Purchase. One of two parties of explorers organized in 1803, by President Thomas Jefferson to map out the Louisiana Purchase. Lewis and Clark followed the Missouri River, while Lt. Zebulon Pike followed the Mississippi River. In 1805, Pike landed at the bluffs below present day Crapo Park and raised the Stars and Stripes for the first time on Iowa soil.

Crapo Park is well known for its plant material. Many different species of trees and shrubs have been planted over the years and the Parks Department continues to add to the variety. Today, there are over 200 species that provide color and beauty throughout the seasons. In addition, the Parks Department plants numerous perennial and annual flowers, which add color from spring to fall. A listing of all trees in the park is available at the park office. A comprehensive listing of trees in this nationally-known arboretum is available in front of the Schnedier House in Crapo Park.

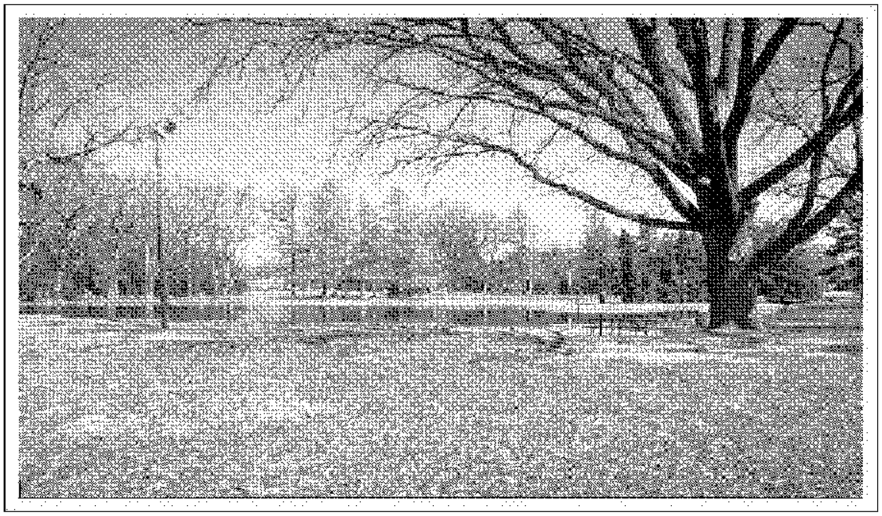
Crapo Park Stop 1
Geologic History of the Mississippi River

For a discussion of the geology and history of the Mississippi River, please see the article by Tassire-Surine, page 3 of this guidebook.

From our gathering area near the Crapo Park Band Shell, we will walk over to the Mississippi River overlook, where Field Trip Leaders will be introduced and Geological Survey Bureau geologist Stephanie Tassier-Surine will lead a discussion of the Geologic History of the Mississippi River.

View up the Mississippi River from the Crapo overlook

Following the discussion of Mississippi River History, we will hike west along the trial past Shakespeare Garden to Lake Starker. Just before we reach the lake we will encounter a monument that was erected above a time capsule, buried at the sight in July of 1996 during a celebration the 100th anniversary of Crapo Park. **Stop 2.** Lake Starker is a 1.5 acre lake that was completed in 1905 when two sinkholes were sealed and flooded. The lake was recently rebuilt after one of the sinkholes suddenly reopened, developing a 20-foot diameter hole that drained the lake over night. Water from the lake flowed through the karst plumbing system and exited out Black Hawk Spring. Lake Starker contains goldfish and is frequented by Canadian geese. The lake is also used for ice skating in the winter.



Stop 2 in Crapo Park is Lake Starker, a water-filled sinkhole.

Departing Lake Starker, we will hike west along the trail past the Corse Statue. This statue was erected in honor of Burlington native General John M. Corse and was the first equestrian statue in Iowa.

When we reach Main Drive we will follow the drive southeast to **Stop 2a**, an area overlooking an active sinkhole. Geological Survey Bureau geologists will lead a discussion of sinkholes. These sinkholes are created by the dissolution of limestone in the Wassonville and Starr's Cave formations.

Stop 2a. Active sinkhole south of Main Drive near the Corse Statue

Following the discussion we will continue east along Main Drive to the head of the Blackhawk Trail.

Crapo Park Stop 3

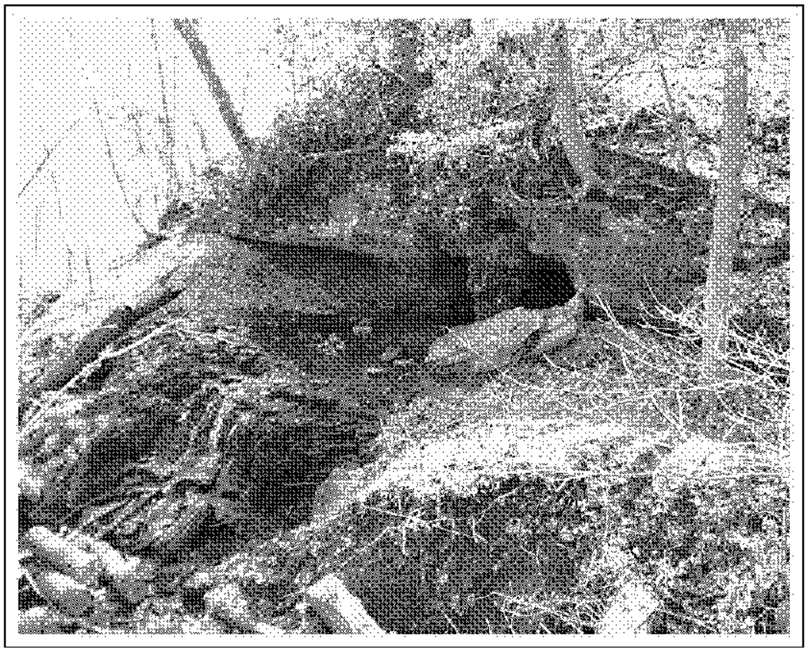
Classic Mississippian Exposures Along Blackhawk Trail, Crapo Park

BEDROCK STRATIGRAPHY IN THE BURLINGTON AREA

For a discussion of the stratigraphy of the rocks, please see page 9 of this guidebook.

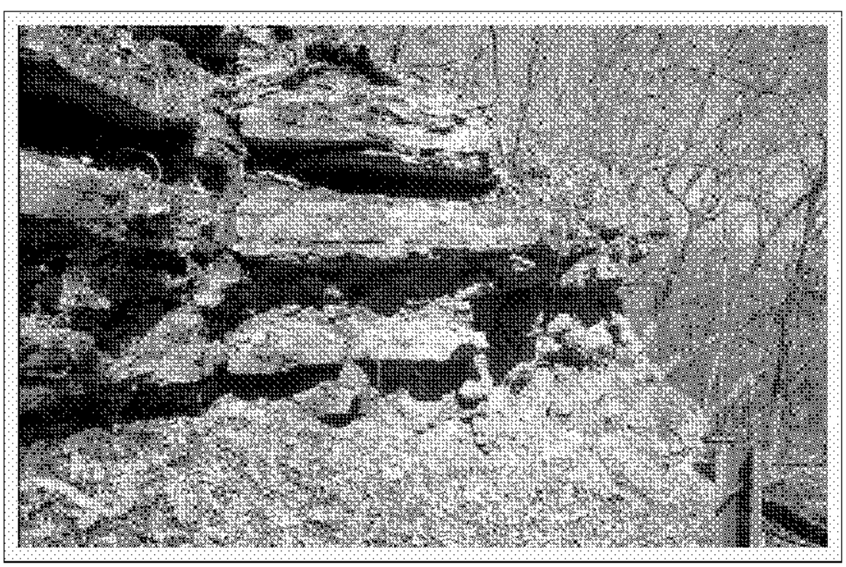
For a measured section of this site, please see page 43 of this guidebook.

The first stop on our hike along the Blackhawk Trail is at Blackhawk Spring. The spring drains the plumbing system that is exposed in the sinkholes that we just examined.

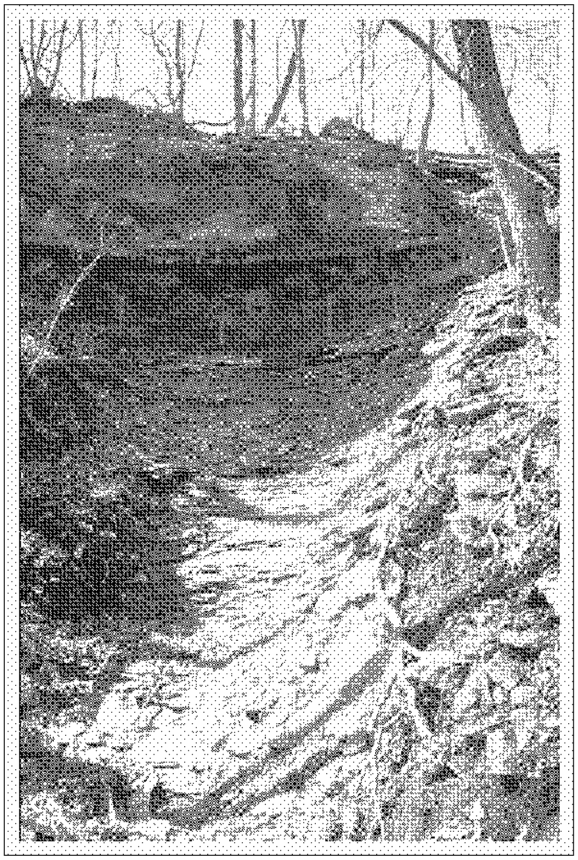


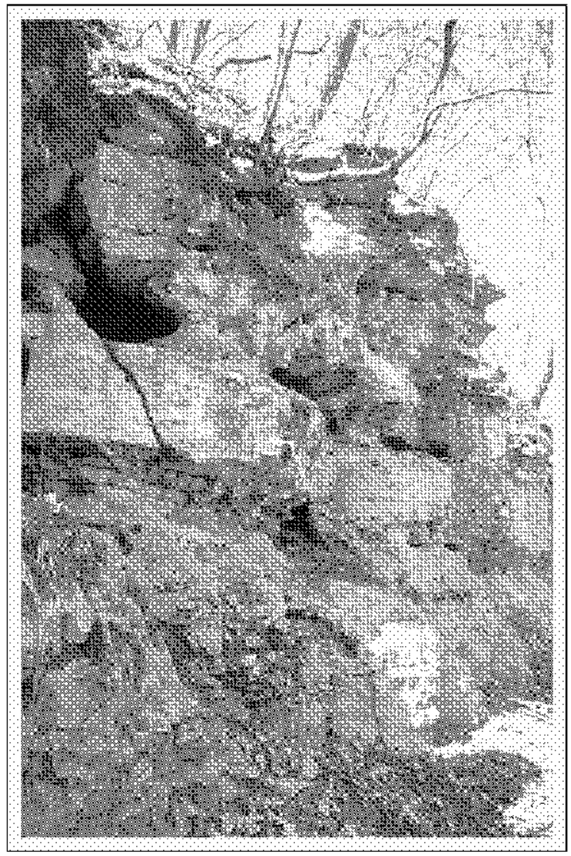
Blackhawk Spring drains sinkholes at Crapo Park

Departing Blackhawk Spring we will walk northeast along the trial just below the bluff line.



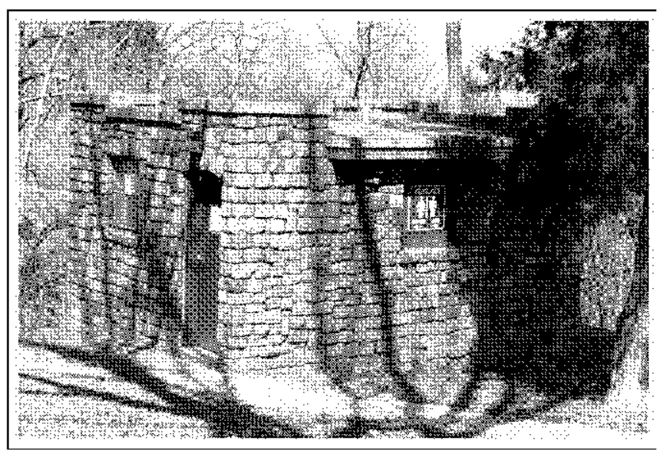
Burlington Formation exposures along Blackhawk Trail





Two views of Mississippian rocks exposed along Blackhawk Trail

Continue north along the Crapo Park bluff line on the Blackhawk Trail, then up hill to the bluff top.

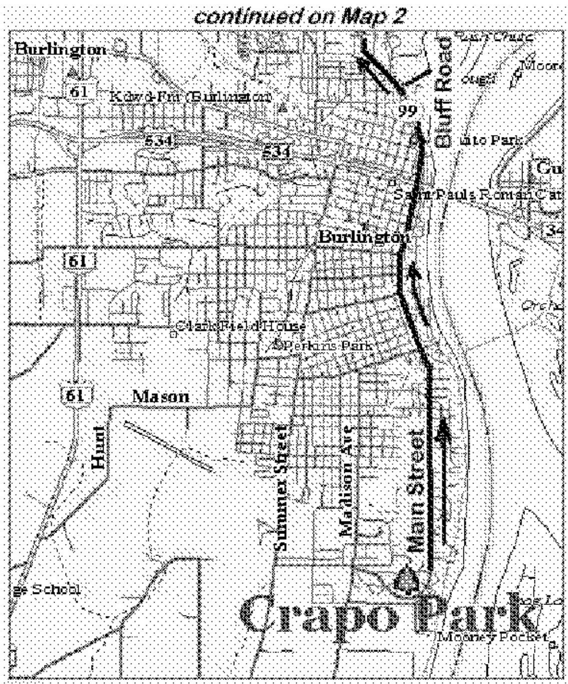


Restroom constructed of Baraboo Quartzite

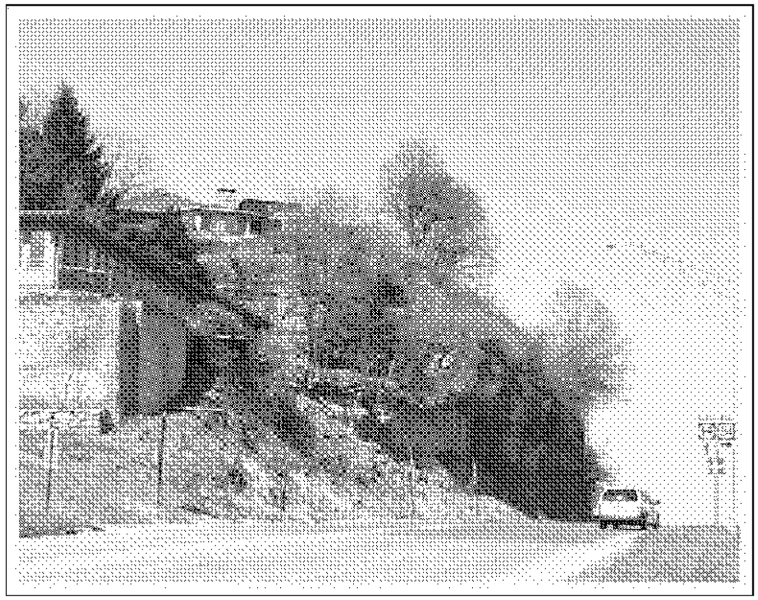
On the way up the hill we pass a restroom constructed with Baraboo Quartzite (about 1.6 billion years old). This rock is among the most durable construction material on Earth. It consists of rounded, sand-size quartz grains cemented together by quartz cement. This unit is exposed near Baraboo, Wisconsin, and southwest Minnesota and adjoining Iowa and Minnesota where it is called the Sioux Quartzite. The unit continues in the subsurface into Nebraska and probably all the way to Arizona. The unit is extensively mined at New Ulm Minnesota and near Sioux Falls, South Dakota as well as Baraboo. An old quarry at Gitchie Manitou State Preserve in northwest Lyon County has not been mined for decades.

This structure, along with several fireplaces built from the same material, was constructed by the WPA during the depression of the 1930s. Crapo Park managers are planning to replace the structure with a more modern facility that will serve park visitors more effectively. The ultimate disposition of this structure has not yet been determined.

Return to your vehicles and depart Crapo Park via the north exit, Main Street and continue through Burlington (see map 1 below) towards Field Trip Stop 2, Starr's Cave Preserve.



Map 1
Route Map from Crapo Park to north Burlington
(see **Map 2** for continuation of route to Starr's Cave)



Bluffs of Mississippian rocks along Bluff Road in Burlington

Road Mileage from Crapo Park to Starr's Cave State Preserve

miles

0 Depart Crapo Park

2.3 Cross Under U.S Hwy 34 in Downtown Burlington, Main St becomes Bluff Rd

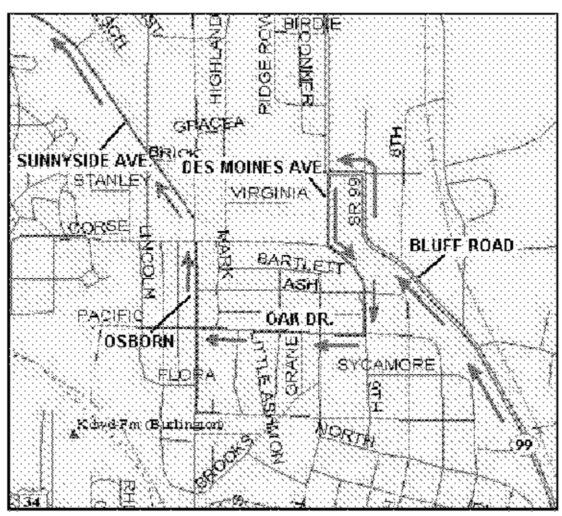
3.6 Pass Illein Manufacturing building

3.8 Turn left (south) on Des Moines Ave (**see Map 2**) and head south passing under stone bridge

4.0 Turn right (west) on Oak St. at 4-way stop and continue west

4.3 Turn right (north) on Osborn at stop sign and drive north

4.5 Angle to the left (northwest) on to Sunnyside Ave at stop light



Map 2
Route map across north Burlington

5.2 Pass Burlington Golf Club on right
continued on following page

Road Mileage from Crapo Park to Starr's Cave State Preserve (***continued***)

miles

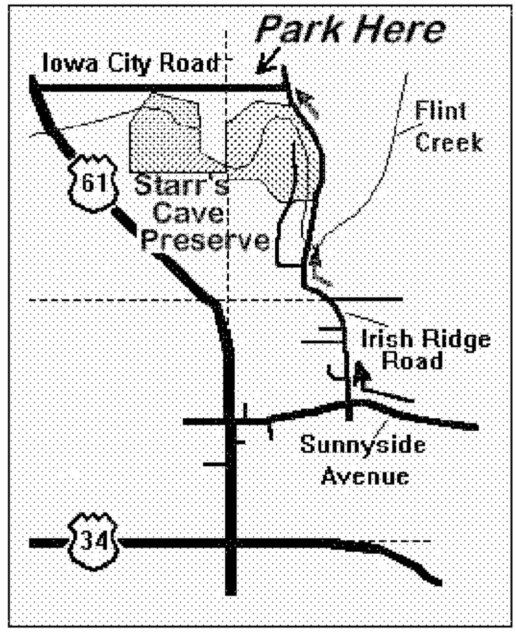
5.7 Turn right (north) on Irish Ridge Road (**see Map 3**)

7.0 Continue north on Irish Ridge Road, passing access to southern part of Starr's Cave Preserve (turn left to access the preserve's nature center, ~1/4 mi)

7.1 Cross Flint Creek

7.8 Continue north on Irish Ridge Road, passing access to Starr's Cave Trail and Overlook

8.0 Turn left (west) on Iowa City Road and park on shoulder
PLEASE PARK WELL OFF ROAD



Map 3
Route map from north Burlington to Starr's Cave Preserve

From here we will hike back to the access to Starr's Cave Trail and Overlook (about ¼ mile).
PLEASE BE ALERT FOR TRAFFIC

Field Trip Stop 2

STARR'S CAVE STATE PRESERVE

INTRODUCTION

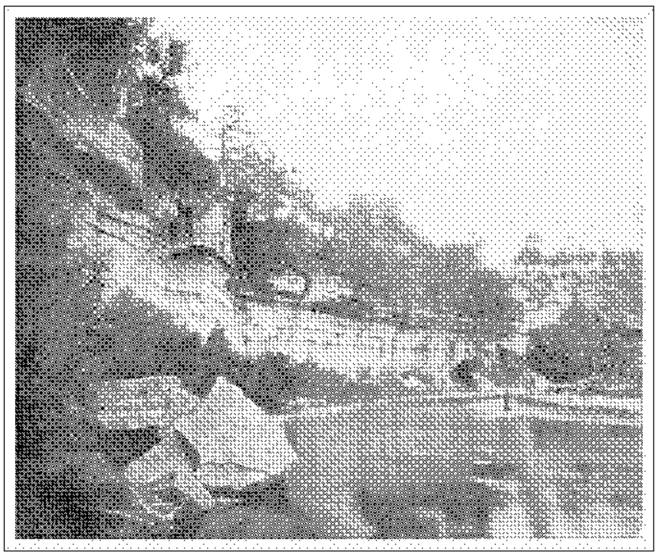
Ray Anderson

Starr's Cave Nature Center and Preserve is a part of the State of Iowa's Preserves System, designated as a geological and biological preserve. The 184-acre preserve is a forested area bordering Flint Creek and was dedicated in 1978. The preserve contains 100–foot limestone bluffs, three caves, prairie remnants, and some endangered plant species. The woodlands range from floodplain to upland and are dominated by oak, walnut, sycamore, and sugar maple.
The Nature Center offers natural history displays, live animals for observation, and scheduled activities, including folk concerts and environmental awareness programs. This center is visited by thousands of children each year and has won awards for its environmental education program. The Nature Center includes teaching and meeting areas and features several interactive exhibits, including a full-size model of a beaver pond. The Leopold Loft contains a collection of Leopold family history and photographs. The grounds around the Nature Center include picnic shelter,

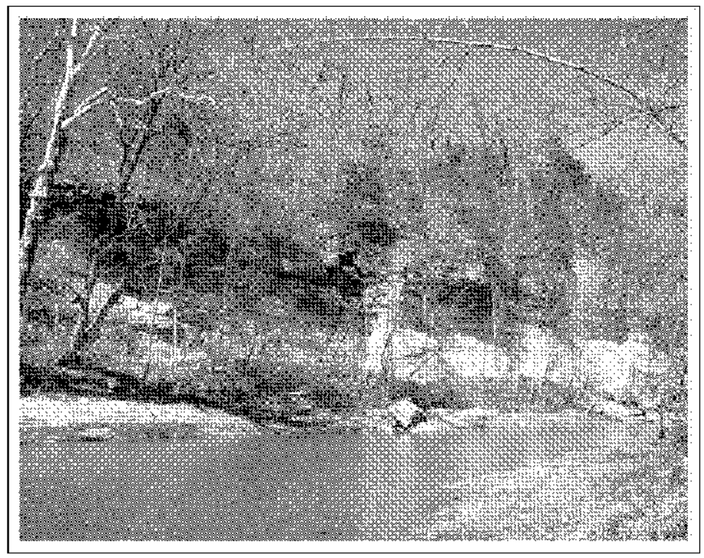
amphitheater, and self-guided nature trails. In addition, the Nature Center offers cross-country ski rental.

Geology of Mississippian Exposures Along Flint Creek, Starr's Cave State Preserve

For a discussion of the stratigraphy of the rocks, please see page 9 of this guidebook.
For a measured section of this site, please see page 47 of this guidebook.



Bluffs along Flint Creek as they appeared in 1895
from Keys, 1895

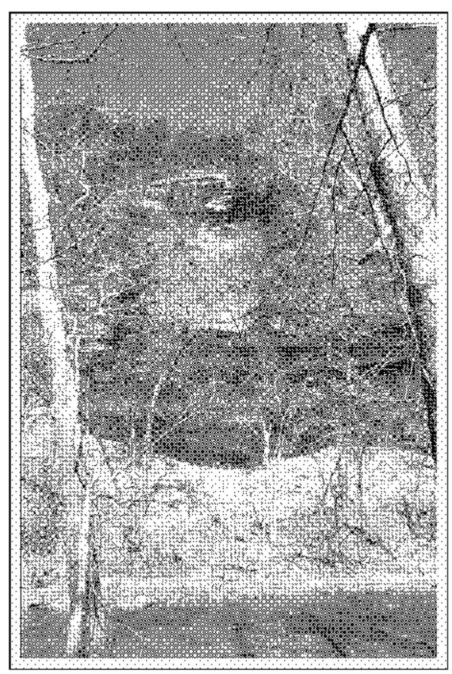


Bluffs along Flint Creek at Starr's Cave today

The exposures of Mississippian strata along Flint Creek, in the area of Starr's Cave State Preserve, have been studied by geologists for well over a century.

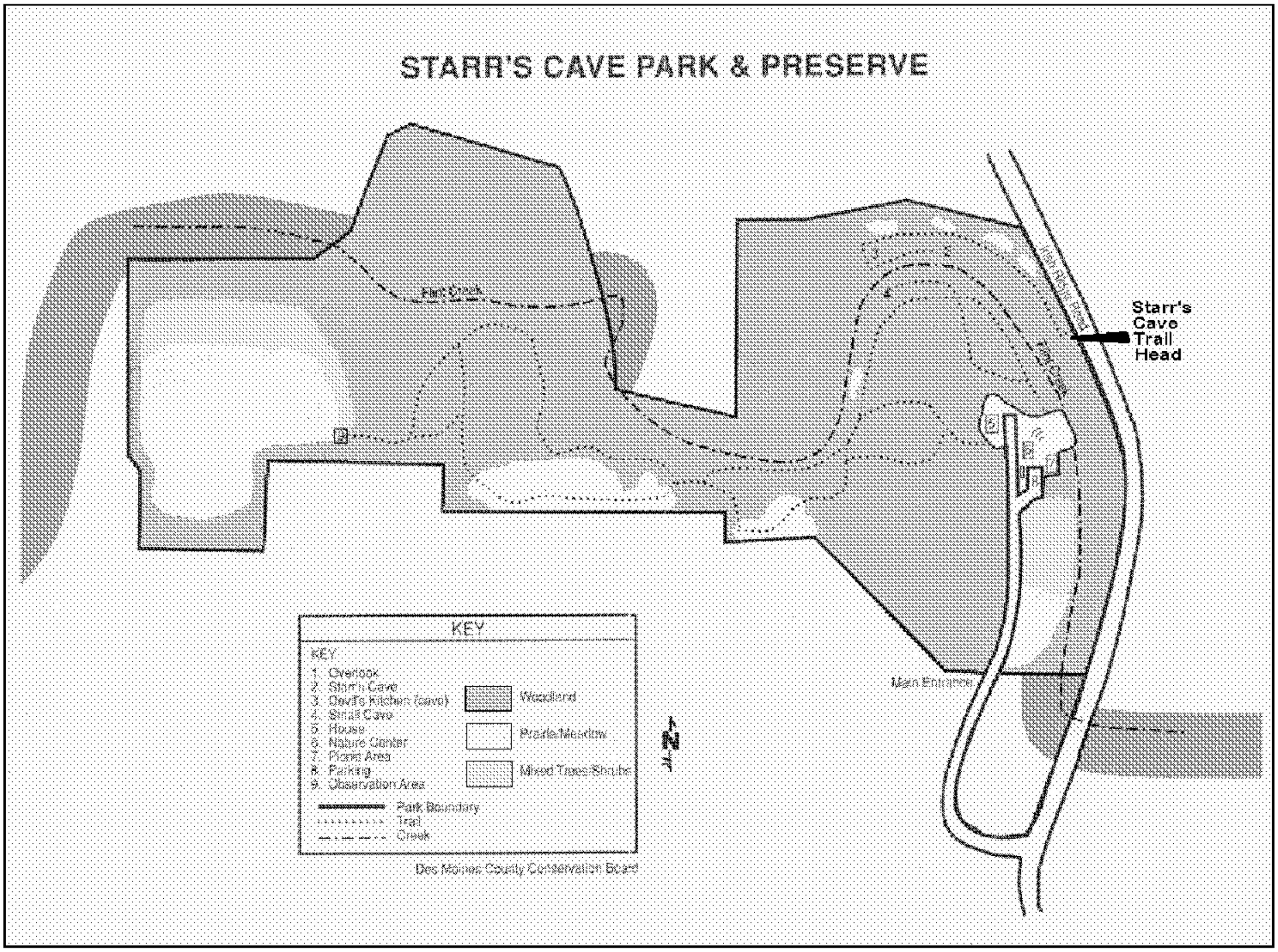
As we enter the preserve area we can enjoy the view of the flood plain of Flint Creek from the overlook, perched over 100 feet above the stream. From the overlook we will proceed north along the bluff-top trail (see map on next page) to a drainage that will provide access to the base of the cliffs. As we reach the Flint Creek the first of the preserve's caves come into view, the Devil's Kitchen. A short distance down stream we will encounter the wood and iron stairway that leads up to Starr's Cave. A steel gate will probably bar the cave's entrance. Arrangements can be made with preserve naturalists to unlock the cave and provide entrance.

PLEASE BE VERY CAREFUL ON THE STAIRS LEADING TO STARR'S CAVE



The overlook at Starr's Cave Preserve
is at the top of this bluff

Geological Survey geologists will lead a discussion of the Mississippian units present at Starr's Cave.



Map of Starr's Cave State Preserve

When the discussion and examination of exposures at Starr's Cave is completed, return up the trial to the entrance at Irish Ridge Road and proceed back to the vehicles.

Depart west on Iowa City Road to **Hwy 61**, then turn right (north) and proceed north for approximately 9 miles to the junction of County Road **H-40** (**see map on back cover of guidebook**). Turn left (west) on H-40 and continue for approximately 8 miles to its intersection with County Road **X-31** and turn left (south). Continue south on X-31 for approximately 5 miles to the bridge over Flint Creek and park along the road on the shoulder north of the bridge.

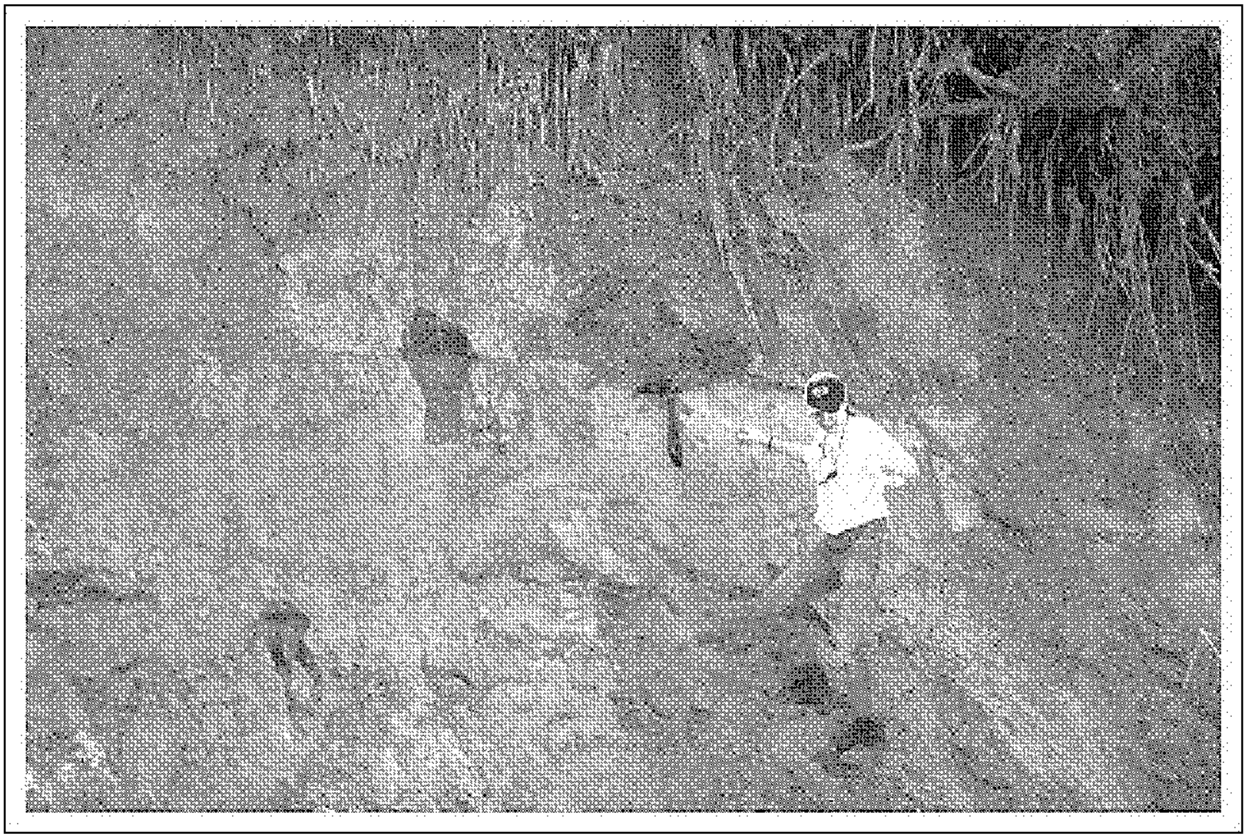
PLEASE PARK WELL OFF ROAD

Walk along the west shoulder of the road to the field access path just north of Flint Creek and follow the path to the north bank of the creek. Walk west along the bank for a few hundred yards to the sand bar across the creek from the large cut-bank.

Field Trip Stop 3

PRE-WISCONSINAN STRATIGRAPHY IN SOUTHEAST IOWA

For a discussion of the geology and history of the Pre-Wisconsinan stratigraphy in southeast Iowa, please see the article by Tassire-Surine, page 21 of this guidebook.



GSB Geologist Stephanie Tassier-Surine on the Pleasant Grove Section, Field Trip Stop 3

INTRODUCTION

Ray Anderson

Field Trip Stop 3 was first described by Hallberg and others on the 27th Annual ***Midwest Friends of the Pleistocene*** field trip in 1980. Called the Pleasant Grove Section, the cut-bank along Flint Creek displays the Kellerville Till Member of the Illinoian Glasford Formation overlying the Hickory Hills Till Member of the Pre-Illinoian Wolf Creek Formation. An intervening fluvial unit was not present in the section described in 1980. Geological Survey

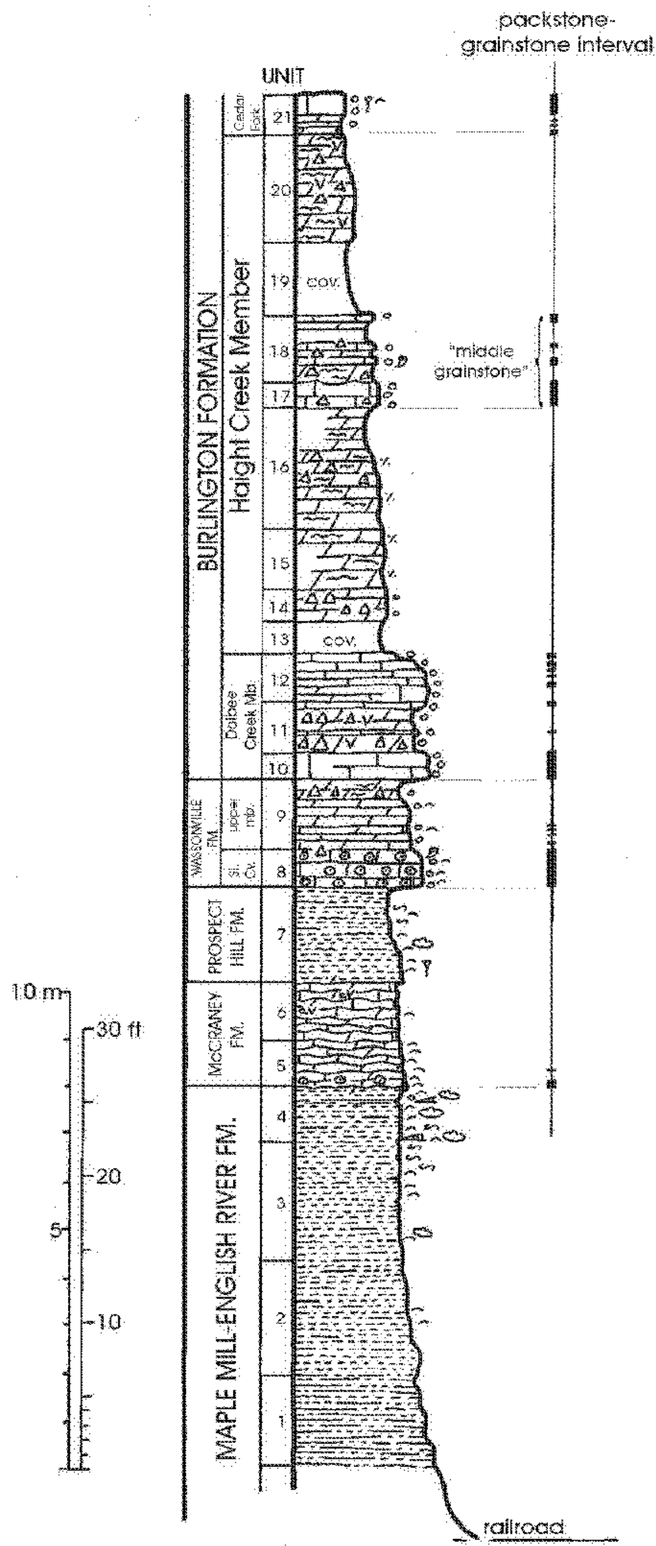
Geologist Stephanie Tassier-Surine will lead a discussion of the Pleistocene units displayed in the cut-bank and other aspects of the Quaternary geology of the region.

This is our last Field Trip Stop. Thanks for participating, and have a safe trip home.

APPENDIX 1: GRAPHIC SECTION OF CRAPO PARK (CITY OF BURLINGTON)

SE NW sec. 16, T69N, R2W, DesMoines Co., Iowa

section description by B.J. Witzke, B.J. Bunker, F.J. Woodson, 5/10/1994



MISSISSIPPIAN - OSAGEAN
Burlington Formation
Cedar Fork Member

Unit 21. Limestone and dolomite; lower half is interbedded dolomite, laminated, and crinoidal packstone lenses; upper half is dominated by crinoidal packstone, minor laminated dolomite 20 cm below top; crinoid cup and large brachiopod (*Spirifer grimesi*) noted near top. 85 cm (2.8 ft).

Haight Creek Member

Unit 20. Dolomite, forms ledges, vuggy, faintly laminated, in thick beds; nodular cherts noted 85 cm, 1.15 m, and 1.65 m above base of unit. 2.2 m (7.2 ft).

Unit 19. Covered interval; some dolomite float observed. Probable dolomite unit. 1.6 m (5.2 ft).

Unit 18. Interbedded limestone and dolomite; lower 35 cm, dolomite, recessive, faintly laminated, very cherty; 35-50 cm above base, crinoidal packstone-grainstone, slightly dolomitic, small cup coral noted; 50-66 cm bove base, dolomite, recessive, cherty; 66-80 cm above base, crinoidal wackestone-packstone ledge, small chert nodule at top; 80-110 cm above base, covered; 12-25 cm below top, dolomite, recessive; top 12 cm, crinoidal wackestone-packstone ledge. 1.35 m (4.4 ft).

Unit 17. Limestone ledges; lower 30 cm, crinoidal wackestone-packstone, contains large chert nodules (to 14 cm thick); upper 15-25 cm, crinoidal wackestone-packstone, coarsens upward, forms large-scale megaripple bedform. 45-55 cm (1.5-1.8 ft).

Unit 16. Dolomite, in discontinuous ledges, very finely crystalline, scattered skeletal molds, part faintly laminated; middle portion of unit with scattered large chert nodules; top 1 m is poorly exposed to covered. 2.55 m (8.4 ft).

Unit 15. Dolomite, discontinuous exposure, scattered small skeletal molds, part faintly laminated. 1.3 m (4.3 ft).

Unit 14. Dolomite, scattered to common crinoid debris molds; 25 cm above base with large chert nodule (to 20 cm thick), 50 cm above base is nodular chert band with silicified crinoid debris. 65 cm (2.1 ft).

Unit 13. Covered interval. Probably includes lower Haight Creek glauconitic dolomite. 70 cm.

Dolbee Creek Member

Unit 12. Limestone, part dolomitic, crinoidal wackestone, interbedded packstone-grainstone lenses and stringers in upper 60 cm. 95 cm (3.1 ft).

Unit 11. Dominantly dolomite and chert, minor limestone, recessive interval; dolomite, scattered crinoid debris molds, scattered large vugs; lower 35 cm, dolomite, very large smooth chert nodules locally encompass entire 35 cm interval; 60-80 cm above base with large chert nodules; 40 cm above base, discontinuous thin crinoidal packstone-grainstone; top 14 cm, crinoidal packstone-grainstone. 1.15 m (3.8 ft).

Unit 10. Limestone, ledge, in 1 or 2 beds; coarse crinoidal packstone-grainstone, very coarse lower 24-30 cm, crinoid stems to 2 cm; fines upward. 56 cm (1.8 ft).

KINDERHOOKIAN
Wassonville Formation
Upper Member

Unit 9. Dolomite dominated, becomes more dolomitic upward, interbedded limestone and dolomitic limestone especially in lower 45 cm; pelloidal limestone noted at base; discontinuous lenses of coarse crinoidal packstone-grainstone noted 15 cm and 30-45 cm above base, lenses to 4 cm thick x 1 m; dolomitic limestone and dolomite with wackestone fabrics, moldic to calcitic brachiopods and crinoid debris scattered through; top 50 cm, dolomite, recessive interval (includes cave entrance), part with faint irregular laminations, scattered chert nodules 35-50 below top (locally to 25 cm diameter); sharp contact at top. 1.45 m (4.8 ft).

Starrs Cave Member

Unit 8. Limestone, ledge former, overhangs upward, top is cave floor; skeletal and oolitic packstone to grainstone, crinoid debris, scattered to common brachiopods (*Rugosochonetes*, *Unispirifer*, *Brachythyris*, etc.), top with scattered small silicified cup corals; nodular chert locally at top, white, chalky (nodules to 3 x 20 cm); upper contact appears gradational. 78 cm (2.6 ft).

Prospect Hill Formation

Unit 7. Siltstone, ledges, slight overhang at base, becomes more recessive upwards; base is dolomitic siltstone forming irregularly cemented bands; coarse silt noted 40 cm above base; 40 cm to 1.65 m above base is siltstone, fine to coarse silt, fines upward, gray but oxidized to light orange brown, scattered shaley partings, fine horizontal laminations scattered through interval, lower part includes molds of brachiopods (includes rhynchonellids, chonetids), bivalves, crinoid cup noted near base, upper part with scattered to common burrows, small brachiopod molds (small spiriferids, small chonetids); upper 32 cm is siltstone, green-gray to tan (oxidized), argillaceous, part laminated to platy. 1.97 m (6.5 ft).

McCraney Formation

Unit 6. Irregularly interbedded pale limestone and darker dolomite; displayed as irregular elongate nodular masses forming “zebra stripes” 3 to 10 cm thick, scattered calcite void fills; limestone is pale brown, dense, sublithographic, limestone locally fractured, fractures filled with dolomite; dolomite, medium to dark brown, very fine to fine crystalline; indeterminate brachiopod noted 70 cm below top of unit. 1.35 m (4.4 ft).

Unit 5. Irregularly interbedded pale limestone and darker dolomite similar to above but higher proportion of limestone; lower 8 to 20 cm is skeletal to oolitic limestone, basal 6-8 cm is skeletal packstone, abundant chonetid brachiopods, very crinoidal; remainder of lower interval displayed as megaripple bedform, wavelengths 1.4-1.6 m, 0-14 cm thick, oolitic packstone, laminated to low-angle cross laminated, top 1 cm interfingers with overlying “zebra” stone;

upper 80 cm irregularly bedded "zebra" striped, lower 15 cm (above oolitic megaripples) with common to abundant brachiopods (rhynchonellids, chonetids, productids), brachiopod-rich stringer 55 cm below top (3-10 cm thick) with common rhynchonellids and chonetids (to 3 cm), rhynchonellids common 48 cm below top, scattered large chonetids (to 3 cm) and rhynchonellids noted 35, 20, 10 cm below top and at top. 90-100 cm (3.0-3.3 ft).

UPPER DEVONIAN (Famennian)

English River/ Maple Mill Formation (Saverton Formation)

Unit 4. Siltstone, argillaceous, medium blue-gray, oxidized to yellow brown upwards, locally slightly dolomitic near top; shale partings 27-35 cm above base; fossil molds generally become larger and more common upwards, scattered bivalves and nautiloids in basal 20 cm; bivalves and brachiopods scattered to common above (includes spiriferids, chonetids, *Chonopectus*), crinoid stem noted 25 cm below top (rhodocrinitid?), nautiloid 20 cm below top; irregular bioturbation especially in lower part; slightly irregular surface at top (3 cm relief). 1.2 m (3.9 ft).

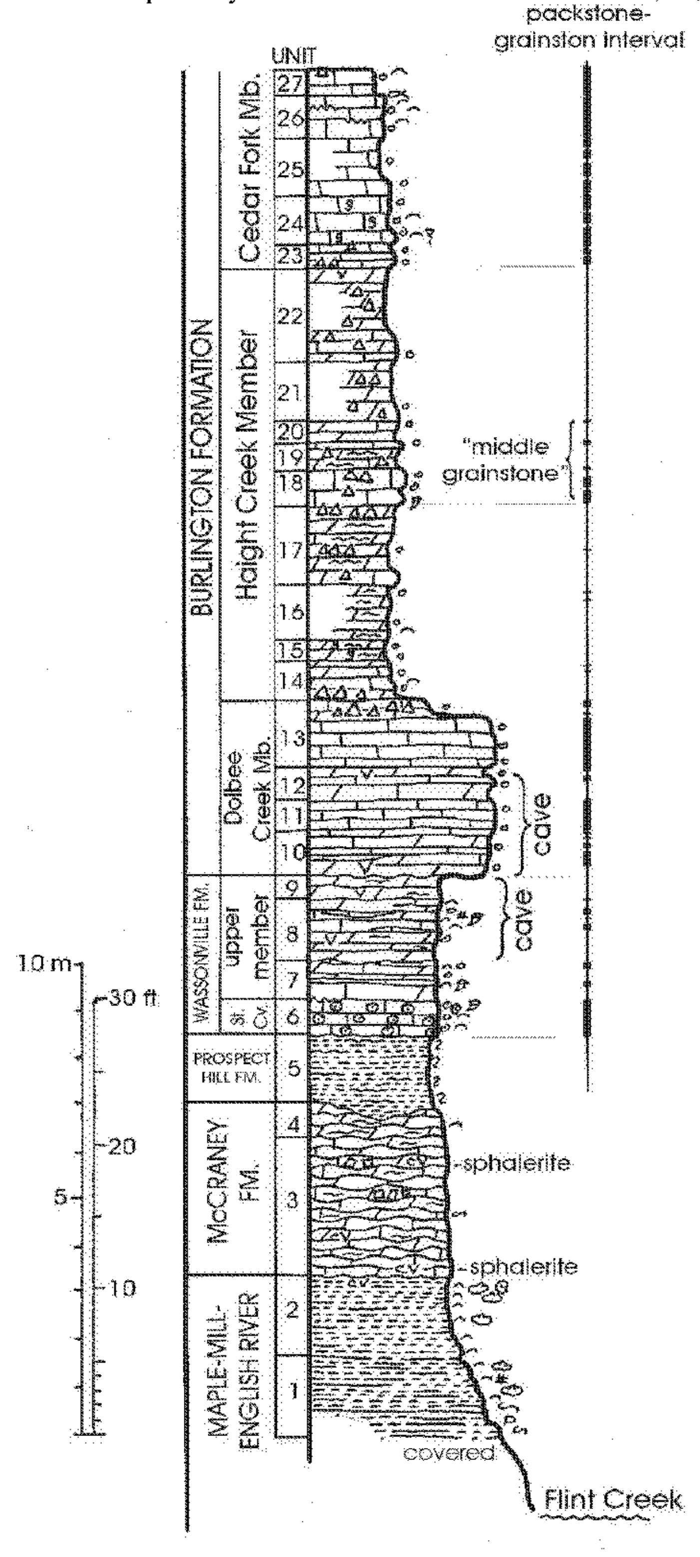
Unit 3. Siltstone, mediium blue gray, argillaceous, becomes less argillaceous upwards; lower interval local ledge-former, upper 1.25 m is local cliff former; bedding breaks noted 35 cm, 80 cm, and 1.25 m below top; scattered brachiopods (spiriferid) and bivalves 2.0 m below top; common molds of brachiopods (Chonopectus) and bivalves 0.8-1.2 m below top; productid brachiopod mold noted 60 cm below top; top 80 cm with scattered horizontal to subhorizontal burrows. Partly covered in lower half; approximately 2.5 m (8.2 ft) thick.

Unit 2. Siltstone, medium blue gray, argillaceous, partly covered, forms small ledges in lower part; gradational below and above; middle part of unit with scattered brachiopod molds. 2.4 m (7.9 ft).

Unit 1. Siltstone, very argillaceous to shaley, and silty shale, medium blue gray, irregular bedding; forms lower part of cascading waterfalls. 1.9 m (6.2 ft) measured thickness; base of unit lies approximately 1.5 m (4.9 ft) above railroad tracks.

APPENDIX 2: GRAPHIC SECTION OF STARR'S CAVE STATE PRESERVE (FLINT CREEK)

NW SE NW and SW SW NE NW sec. 19, T70N, R2W, DesMoines Co., Iowa
section description by Brian J. Witzke and Bill J. Bunker, 11/12/1997



MISSISSIPPIAN - OSAGEAN
Burlington Formation
Cedar Fork Member

Unit 27. Limestone, crinoidal packstone-grainstone; in two beds, lower 25 cm very coarse crinoidal, horn coral noted; upper 35 cm medium to coarse crinoidal, chert nodule at top, large *Spirifer grimesi*. 60 cm (2.0 ft).

Unit 26. Limestone, dominantly fine- to coarse-grained crinoidal packstone-grainstone, stylolites common in upper half; 60-76 cm above base is skeletal wackestone-packstone; upper 12 to 17 cm with silicified crinoidal debris and brachiopods, common to abundant large *Spirifer grimesi* (to 6 cm), fish bone noted at top. 92 cm (3.0 ft).

Unit 25. Limestone, crinoidal packstone-grainstone and wackestone-packstone, partly covered, basal 34 cm is wackestone-packstone ledge. 1.24 m (4.1 ft).

Unit 24. Limestone, crinoidal packstone and packstone-grainstone, traces of glauconite through most of unit; lower 28 cm forms ledge, fine crinoidal packstone at base, coarsens upward to coarse-grained crinoidal packstone, crinoid cup noted, scattered silicified crinoid debris and brachiopods; 28-60 cm above base slightly recessive fine to medium crinoidal packstone, silicified crinoid debris at base; upper 42 cm includes fine to coarse crinoidal packstone-grainstone and packstone, faint laminations concentrate glauconite, lower and middle parts with scattered large brachiopods. 1.02 m (3.35 ft).

Haight Creek Member

Unit 23. Limestone and dolomite; lower 20 cm is limestone, crinoidal packstone, scattered large chert nodules (to 20 cm); 20-36 cm above base, limestone, crinoidal wackestone to packstone; top 20 cm, limestone, recessive, fine crinoidal wackestone-packstone, chert nodules. 56 cm (1.8 ft).

Unit 22. Dolomite to dolomitic limestone; lower 20 cm prominent bed, dolomitic limestone, wackestone, scattered crinoid debris, scattered chert nodules; 20-65 cm above base ledges of vuggy dolomite and calcitic dolomite, scattered crinoid debris molds, interval also includes calcitic crinoidal wackestone, chert nodules scattered through (4-15 cm diameter); 30-130 cm below top is mostly covered, float indicates dolomite with chert nodules; top 30 cm is dolomite, vuggy, part covered. Approximately 1.95 m (6.4 ft).

Unit 21. Dolomite to dolomitic limestone, poorly exposed; dolomite with scattered crinoid debris molds; scattered chert nodules in lower 40 cm, large chert nodules 45 cm below top of unit. Approximatley 1.2 m (3.9 ft).

Unit 20. Dolomite, scattered crinoid debris molds; discontinuous lenses of dolomitic limestone, crinoidal wackestone-packstone in upper part; part poorly exposed. 50 cm (1.6 ft).

Unit 19. Dolomite to dolomitic limestone, dense, recessive, faintly laminated, scattered large chert nodules; upper 16 cm is ledge former, limestone, fine to medium crinoidal packstone. 61 cm (2.0 ft).

Unit 18. Limestone, crinoidal packstone, in two beds; lower 36 cm with coarse crinoid debris, brachiopods, horn coral at base, fine to medium packstone upward, scattered chert nodules in upper part; upper 39 cm with large nodular to bedded chert, dense, smooth, faintly laminated mudstone fabrics, 5 to 20 cm thick at top and bottom of upper interval; upper interval with interbedded limestone, fine to medium crinoidal packstone. 75 cm (2.5 ft).

Unit 17. Dolomite to dolomitic limestone; basal 35 cm ledge, calcitic dolomite, scattered chert nodules; 35-65 cm above base, dolomite, faintly laminated; 65-80 cm above base, large chert nodule, white, smooth, partly a silicified crinoidal wackestone to packstone; 80-110 cm above base, dolomite to dolomitic limestone, skeletal wackestone in lower part, faintly laminated dolomite in upper part; 110-138 cm above base, dolomite, faintly laminated; top 27 cm, nodular to bedded chert, nonskeletal mudstone fabric, faintly laminated, silicified large crinoid debris on upper surface. 1.65 m (5.4 ft).

Unit 16. Dolomite, poorly exposed, lower part with scattered silicified brachiopod and crinoid debris, faintly laminated at base; upper part with scatttered skeletal debris and thinly interbedded stringers of dolomitic limestone (crinoidal packstone). 1.2 m (3.9 ft).

Unit 15. Dolomite, recessive, very finely crystalline, part faintly laminated, scattered to common fine glauconite grains (dark green) especially along laminae; glauconite content generally decreases upward. 40 cm (1.3 ft).

Unit 14. Dolomite and dolomitic limestone; basal 23 cm is crystalline dolomite interval with very large chert nodules (to 20 x 50 cm); 23-52 cm above base, dolomite and dolomitic limestone, scattered crinoid and brachiopod molds, also includes fine crinoidal packstone; 52-68 cm above base, narrow ledge, dolomite to dolomitic limestone, dense, burrowed, scattered crinoid debris molds at top (including *Platycrinites*), part with calcitic crinoid debris; top 14 cm is recessive dolomite, scattered skeletal molds, includes minor dolomitic limestone (crinoidal packstone), gradational above. 82 cm (2.7 ft).

Dolbee Creek Member

Unit 13. Limestone, crinoidal packstone-grainstone; very coarse crinoidal packstone-grainstone in basal 15 cm, 28-40 cm above base, 55-75 cm above base; remainder is primarily fine to medium crinoidal packstone-grainstone, part slightly dolomitic; upper 40-45 cm crinoidal packstone contains very large chert nodules (70 x 25 cm; 170 x 35 cm), smooth chert, silicified skeletal mudstone to wackestone; laterally discontinuous thin dolomite, skeletal moldic, 45-50 cm below top Approximately 1.4 m (4.6 ft).

Unit 12. Dominantly dolomitic limestone; basal 33 cm dolomitic limestone, sparsely crinoidal wackestone fabric; 33-42 cm above base, limestone, very coarse crinoidal packstone-grainstone, fines upward, large-scale bedform; upper 25 cm is recessive, dolomite to dolomitic limestone, vuggy, sparse skeletal molds, scattered crinoid debris molds, top 7 cm is discontinuous crinoidal packstone lens. 67 cm (2.2 ft).

Unit 11. Limestone, crinoidal packstone-grainstone, a stacked series of graded bedforms each coarse to very coarse at the bases, fine to medium upward; succession of graded units 19, 10, 9, 8 12, and 6 cm thick; Platycrinites stem segments noted; prominent bedding break 47 cm above base. 65 cm (2.1 ft).

Unit 10. Dolomite and limestone; overhang at base, irregular base with up to 10 cm relief; lower 43-45 cm is dolomite to dolomitic limestone, part vuggy, scattered crinoidal molds, some calcitic crinoid debris, discontinuous thin crinoidal packstone stringers in upper 16 cm; 43-55 cm above base is limestone, part dolomitic, crinoidal packstone, laterally replaced by crinoidal wackestone, crinoid stems and columnals; upper 40 cm is limestone and dolomitic limestone, lower half with discontinuous crinoidal packstone stringers, prominent crinoidal packstone-grainstone at base, upper half is dolomitic limestone with discontinuous crinoidal wackestone-packstone lenses. 95 cm (3.1 ft).

KINDERHOOKIAN
Wassonville Formation
Upper Member

Unit 9. Dolomite, nodular to irregular bedded aspect, "zebra-striped" appearance in part, wavy to contorted laminations best developed in lower 15 cm; scattered vugs; upper surface irregular with up to 10 cm relief locally; overhang above. 53 cm (1.7 ft).

Unit 8. Dominated dolomite and dolomitic limestone; lower 68-76 cm is dolomite, part vuggy, faint hummocky to laminated fabric; upper 60-70 cm dominantly dolomitic limestone, skeletal wackestone fabric, scattered crinoid debris and brachiopods, part moldic, interbedded with limestone, skeletal packstone lenses and discontinuous beds (to 20 cm thick), most prominently developed 68 to 106 cm above base, locally in top 10 cm; brachiopods (*Rugosochonetes*, *Unispirifer*, *Brachthyris*, *Spinocarinifera*, etc.), crinoid debris, bryozoans, cup corals. 1.3-1.38 m (4.3-4.5 ft).

Unit 7. Limestone to dolomitic limestone, locally dolomite to dolomitic limestone in upper part, increasingly dolomitic upward; dominantly a skeletal wackestone with scattered to common brachiopods (*Spinocarinifera*, Schellwienella, etc.), crinoid debris, scattered cup corals; argillaceous streak 13 cm above base; starved lenses and discontinuous bedforms of coarse crinoidal packstone locally noted 29-40 cm above base and top 10 cm, top packstone forms starved megaripples with 1.3 m wavelength (top of unit 0-10 cm thick); upper dolomite locally with stringers of crinoidal molds. 78-88 cm (2.6-2.9 ft).

Starrs Cave Member (type section)

Unit 6. Limestone, oolitic and skeletal packstone to grainstone; very fossiliferous with brachiopds (Rugosochonetes, *Unispirifer*, *Brachythyris*, *Schellwienella*, *Rhipidomella*, etc.), crinoid debris (coarse at top), scattered gastropods, cup coral (noted at top); prominent stylolite at top of unit; silicified domains locally in upper part (not quite developed into nodular chert). 74 cm (2.4 ft).

Prospect Hill Formation

Unit 5. Siltstone, light brown gray, part tinted light green, part slightly argillaceous; 40

cm erosional incision locally at base, infills depression (channel form); basal fill, finely laminated to low-angle cross laminated, penetrated by vertical to subvertical burrows (10 cm maximum burrow penetration); remainder of unit finely laminated to low-angle cross laminated (hummocky), scattered vertical burrows penetrate across laminae; thin discontinuous light green-gray noncalcareous shale along upper surface (0-5 cm thick); thin shale parting 10 cm below top; 5-6 cm relief locally noted along upper surface. 1.45-1.85 m (4.8-6.1 ft).

McCraney Formation

Unit 4. Dolomite, part calcitic, light brown, part with faint wavy laminations; rare rhynchonellid brachiopod molds noted; erosional upper surface displays up to 40 cm relief (over a horizontal distance of 3 m). 30-70 cm (1.0-2.3 ft).

Unit 3. Limestone and dolomite, alternations of light-colored elongate nodular limestone and darker colored dolomite create an irregular "zebra-striped" pattern on exposure, unit is approximately 2/3 limestone, 1/3 dolomite; limestone, dense, light buff, part finely laminated, laminations irregular to wavy, limestone beds displayed as elongate nodular-like bedforms, scattered stylolites, limestone is fractured in part, fractures filled with dolomite; dolomite, very fine to finely crystalline, light medium to medium brown; unit has scattered calcite void fills (to 15 cm diameter), sphalerite noted in calcite void fills at base and 50 cm below top of unit; fractured dense limestone locally brecciated, 1-5 cm limestone clasts in dolomite matrix, breccia noted 50 cm and 1.3 m below top of unit. 3.0 m (9.8 ft).

UPPER DEVONIAN (Famennian)
English River/ Maple Mill Formation (Saverton Formation)

Unit 2. Siltstone, light medium to medium gray, part slightly argillaceous, part slightly burrowed; part pyritic (oxidized to sulfate blooms on upper surface); fossil molds scattered to common, most common in upper 50 cm, brachiopod-rich lens 20 cm below top; scattered calcite void fills in upper part; brachiopods include *Chonopectus*, *Whidbornella*, *Mesoplica*, *Schizophoria*, *Syringothyris*, others; bivalves (pelecypods) scattered to common in upper part; scattered gastropods; up to 10 cm of relief locally developed on upper surface. 1.75-1.85 m (5.7-6.1 ft).

Unit 1. Siltstone and silty shale; dominantly siltstone, medium gray, slightly argillaceous to argillaceous; shale, medium dark gray to green-gray, silty to very silty, gradational with siltstone intervals, shale partings at top and 115 cm below top; shale dominated 20 to 40 cm above base with scattered phosphatic grains; pyritized burrows 50 cm above base; upper 1.15 m siltstone interval with scattered to common fossil molds including bivalves, fenestellid bryozoans, brachiopods (as in unit 2). 1.65 m (5.4 ft) thick; an additional 1.7 m (5.6 ft) covered below to level of Flint Creek, probably shale-dominated.

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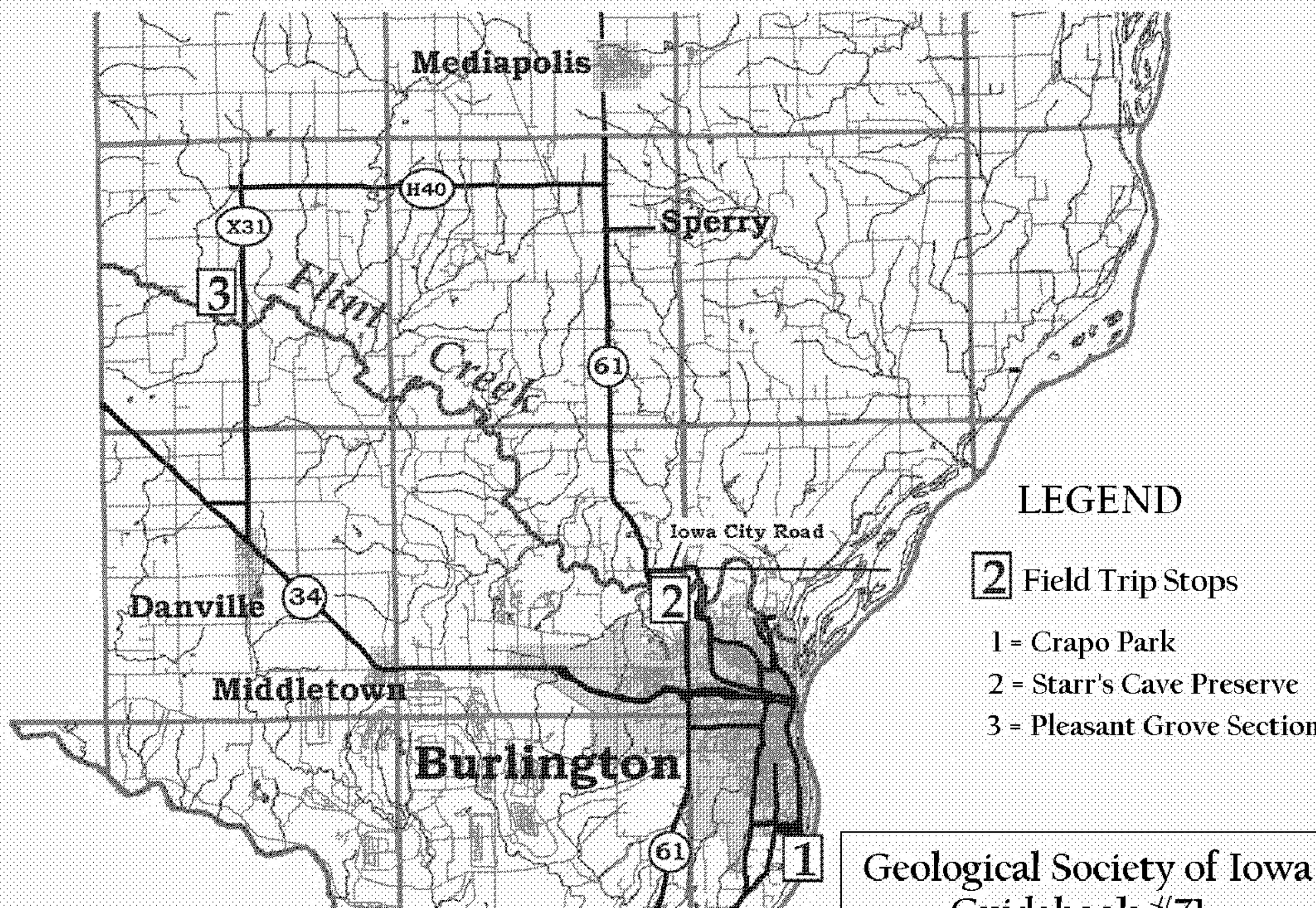
CLASSIC GEOLOGY OF THE BURLINGTON AREA: DES MOINES COUNTY, IOWA



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