GEOLOGIC FEATURES IN SOUTHEASTERN LINN COUNTY, IOWA

edited by
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and
Chad L. Fields

Geological Society of Iowa

April 12, 2008 *Guidebook 82*

Cover Photograph

The cover photo is a satellite image from Google Earth of the Hennessey Quarry, along Old River Road and the Cedar River southeast of Cedar Rapids. The quarry will be out principal stop on this field trip.

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Guidebook 82

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TABLE OF CONTENTS

INTRODUCTION TO THE GEOLOGY OF SOUTHEAST LINN COUNTY, IOWA

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On today's field trip we will examine some of the geological features of southeast Linn County. Prior to departing for the first stop we will have a brief parking lot discussion of the geological features that we will be examining. These include the Pleistocene features that sculpt the landforms that we see in the area, including the development of the Iowan Surface by erosion of loess-capped Pre-Illinoian glacial deposits between about 16,500 and 21,000 years ago. Deb Quade (IGS) will describe the erosion produced the gently rolling Iowan Surface landscape and the distinctive linear paha ridges, including the Kirkwood Paha on which Kirkwood College is

A view of the Kirkwood Paha looking north along Kirkwood Boulevard.

located (see photo below). We will discuss the structure of a paha and what it tells us about the history of the Iowan Surfaces that has since been lost. We will also discuss the advance of the Wisconsin Glacier into central Iowa that sent huge volumes of silt down the Cedar River, much of which blew out of the river's floodplain and deposited on the adjacent uplands as thick sequences of Peoria Loess. Then Deb will review what we will see at the Hennessey Quarry, field trip Stop!

Then Ray Anderson will briefly discuss the Silurian and Devonian rocks that are seen at the bedrock surface in this area and their relationship to the Plum River Fault Zone, and will describe the rocks that we will see at our first stop in the Hennessey Quarry. Finally, Chad Fields will describe Field Trip Stop 2 where he will tell us a little about the history of the Cedar River and its environmental challenges that it is currently facing.

Depart the parking area by car and caravan to Field Trip Stop 1, the Bruening Rock Products Hennessey Quarry located on Old River Road South of Cedar Rapids (see map on back of guidebook). Follow Tower Road south and west to Kirkwood Blvd.

Turn left on Kirkwood and proceed south for one block to 76th Ave. Dr. Turn left on 76th and continue east for one mile to C Street.

Turn left and drive north on C Street for 2 miles, crossing Highway 30 and continuing to the Prairie Creek Power Plant at Ely Road.

Turn right on Ely road and proceed through the on-way stone tunnel under the railroad track, then quickly turn left on Old River Road that parallels the Cedar River. Continue east and north on Old River Road for about 1¼ miles to the entrance of Bruening Stone Products Hennessey Quarry and proceed into the quarry following the instructions of the field trip leader.

The Hennessey Quarry is potentially very dangerous, so it is very important that everyone follows the instructions of the field trip leaders at this quarry. At the quarry we will see and discuss the Devonian rocks of the Wapsipinicon Group beginning with the Coggan and Cedar Rapids members of the Otis Formation and the overlying Kenwood, Spring Grove, and Davenport Members of the Pinicon Ridge Formation. We will then hike up to the benched bedrock surface at the top of the quarry where we will see exposures of the very basal-most rocks of the Solon Member of the Little Cedar Formation (Cedar Valley Group). We will also see well developed glacial striations, oxidized Pre-Illinoian till displaying a late-Sangamon Geosol, a thin Pisgah Formation silt, a poorly-developed Farmdale Geosol, and a thick sequence of Peoria Loess. After viewing and discussing these geologic units we will proceed to Stop 2.

Exit the Hennessey Quarry and turn left (southwest) on Old River Road. Proceed for about 1 mile to the parking area across the road from the Shack Tavern.

At Field Trip Stop 2, the final stop of the day, Chad Fields will lead a discussion of the Cedar River, its history and modern water quality concerns. He will describe the results of the TMDL (Total Maximum Daily Load) report that he has recently completed for the Cedar River.

WE HOPE THAT THIS FIELD TRIP IS AN ENTERTAINING AND EDUCATIONAL EXPERIENCE FOR ALL PARTICIPANTS. THANK YOU FOR JOINING US AND WE ALL HOPE THAT WE WILL SEE YOU AT FUTURE GEOLOGICAL SOCIETY OF IOWA FIELD TRIPS

QUATERNARY GEOLOGY NEAR THE BRUENING ROCK PRODUCTS HENNESSEY QUARRY, CEDAR RAPIDS, IOWA

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INTRODUCTION

The area examined for this trip lies near the border of the Southern Iowa Drift Plain and the Iowa Erosion Surface Landform Regions (Fig. 1). This area has a rich and complex geologic history punctuated by at least seven periods of glaciation between 2.2 million and 500,000 years ago. Subsequent erosion and ensuing drainage development have created a landscape of the steeply rolling topography that is characteristic of the Southern Iowa Drift Plain landform region. In this area, these Pre-Illinoian Episode glacial deposits are mantled by Pre-Wisconsin age colluvial (pedisediment)and Wisconsin age eolian materials (loess). During the Wisconsin Episode glacial advance a period of intense cold resulted in massive erosion in the northern part of Iowa forming the landform region known as the Iowan 'Erosion' Surface. The Iowan Surface comprises all of Linn County, and is characterized by landscapes forming a complex mosaic of broadly stepped Wisconsin erosional surfaces cut into Pre-Illinoian Quaternary sequences, Wisconsin and Holocene alluvial surfaces, Wisconsin and Holocene eolian landforms, and intermittent areas of Paleozoic bedrock exposure. The stepped erosional surfaces were formed by stream action, slope wash and wind deflation during a period of intense freeze and thaw activity (periglacial) that occurred between 21,000 and 16,500 years ago during the coldest part of the Wisconsinan Episode. Field trip participants will have the opportunity to see a section exposed at Hennessey Quarry that is more typical of the exposures adjacent to river valleys of the Southern Iowa Drift Plain

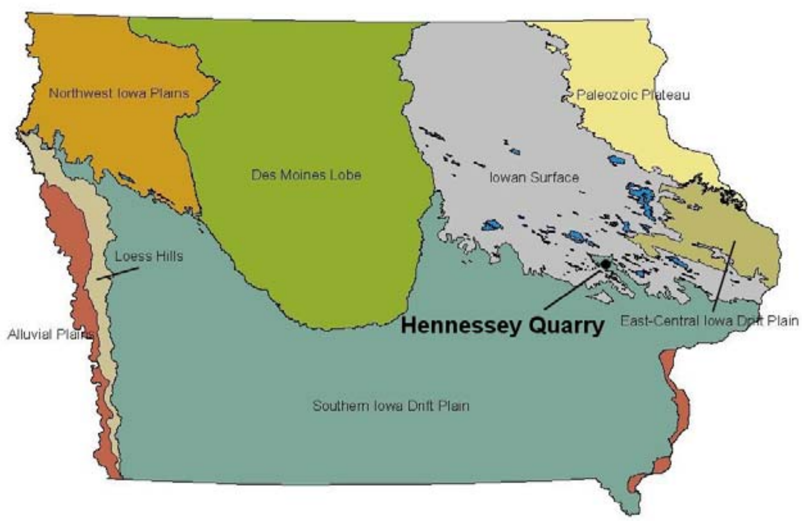


Figure 1: Landform regions of Iowa (Prior, 1991) showing the location of Hennessey Quarry.

REGIONAL STRATIGRAPHIC UNITS

The stratigraphic framework of east-central Iowa consists of materials from the Pre-Illinoian, Illinoian, Wisconsin and Hudson episodes. Units exposed at the Hennessey Quarry include Pre-Illinoian till, the Late Sangamon Geosol, and Wisconsin age loesses. Pre-Illinoian materials are composed of glacial tills of the Wolf Creek and Alburnett formations as well as the intervening paleosols and unnamed sand and gravel units (Hallberg, 1980). The Wolf Creek Formation is subdivided into the Winthrop, Aurora and Hickory Hills till members (oldest to youngest). The Alburnett Formation till members are 'undifferentiated'. Although multiple till members may all be present in one area, laboratory analyses are necessary for differentiation. It is difficult to determine which till member is present from field descriptions alone, especially in areas where only one till is present. Generally speaking, the till units are all massive, uniform, loam textured basal tills.

East-central Iowa is mantled by two Wisconsin Episode loess deposits, the Peoria and Pisgah formations. These materials may overlie glacial till, Wisconsin age alluvium or unnamed Erosion Surface sediments. The Peoria Formation includes wind-blown materials and two facies are recognized: a silt facies (loess) and a sand facies (eolian sand). Materials are well-sorted, may be interbedded and range in texture from silt to medium sand. The Peoria Formation is time-transgressive, with deposition occurring between approximately 23,000 and 11,000 RCYBP (Bettis, 1989). Loess deposition was most rapid from about 21,000 to 16,000 years ago during the period of intense cold associated with the Iowan Surface.

The Pisgah Formation originated as eolian silt and was altered by a combination of colluvial hillslope processes, pedogenic and periglacial processes. The Pisgah ranges in texture from silt loam (loess) to loamy sand and includes loess, colluvium, slope deposits and mixing zone materials. The Pisgah Formation was previously referred to as the 'basal Wisconsin loess' (Ruhe, 1969) or the 'basal Wisconsin sediment' and is the stratigraphic equivalent of the Roxanna Silt of Illinois and the Gilman Canyon Formation of Nebraska, although the lithologic properties vary (Bettis, 1990). Pedogenic alteration at its base has resulted in its incorporation with the underlying Sangamon Geosol. The Pisgah Formation is typically much thinner than the Peoria Formation and has the Farmdale Geosol developed on its surface. The Pisgah Formation was deposited between approximately 30,000 and 24,000 RCYBP (Bettis, 1989).

The Farmdale Geosol is an interstadial soil that represents a brief period of landscape stability during the Wisconsin glacial. It is expressed as a thin, dark grayish brown buried soil, and commonly contains charcoal. Periglacial activity has often altered the contact resulting in a discontinuous or mixed horizon. The Farmdale is widespread throughout the Midwest and is commonly identified in Illinois and Indiana (Hall and Anderson, 2000). Dates for the Farmdale Geosol range from 28,000 to 16,500 RCYBP (Bettis, 1989).

LANDFORM REGIONS OF EAST-CENTRAL IOWA

Iowa is divided into seven distinct landform regions: the Des Moines Lobe, Loess Hills, Southern Iowa Drift Plain, Iowan Surface, Northwest Iowa Plains, Paleozoic Plateau, and Alluvial Plains (Prior, 1991). The boundary between the Southern Iowa Drift Plain to the south and the Iowan Surface to the north occurs in east-central Iowa. The map unit classifications are based on a combination of landscape features, geologic materials, and slope elements. Each landscape region is associated with a series of depositional or erosional events and contains materials characteristic of those genetic processes. Prior's 1991 map has since been revised (Prior and Kohrt, 2006). On a large scale, the basic regions are the same; however, better imagery and data allowed for more detailed delineation of the boundaries and better identification of additional surface features such as paha and parabolic dunes.

Southern Iowa Drift Plain

The Southern Iowa Drift Plain is the largest of Iowa's landform regions and comprises the southern portion of the state. This landform region is characterized by steeply rolling landscapes and well-developed drainage divides. Iowa has been glaciated at least seven times between approximately 2.2 million and 500,000 years ago (Boellstorff, 1978a,b; Hallberg, 1980, 1986) and has undergone alternating periods of landscape stability and erosion since that time. The great amount of time since the last glacial advance in this area has allowed for the development of an integrated drainage network and resulted in the destruction of the features typically associated with glacial landscapes. Glacial till overlain by various thicknesses of loess deposits dominate this landform region.

Iowan Surface

In contrast to the Southern Iowa Drift Plain, the Iowan Surface to the north was the result of a period of intense cold from 21,000 to 16,500 years ago during the Wisconsin full glacial (Bettis, 1989). The Iowan Surface is the predominant landform region in northeastern Iowa and level rolling topography and limited exposures are typical of this landform region.

Historical Studies

The origin of the Iowan Surface has long been debated. Early researchers believed it was a separate glacial advance, but could not agree as to which glacial episode this advance was related. Most early researchers (McGee, 1891; Calvin, 1899; Alden and Leighton, 1917; Kay and Apfel, 1929) held that the Iowan Drift was a stage between the Illinoian and Wisconsin. The Iowan was later assigned to the earliest substage of the Wisconsin (Leighton, 1931, 1933; Kay and Graham, 1943). As a third option, Leverett (1909, 1926, 1939) believed the Iowan represented the last part of the Illinoian, but later conceded (1942). Debate on its placement within the Wisconsin continued into the 1950's, when Leighton and Willman (1950) placed the Iowan as the next younger stage of the Wisconsin after the Farmdale was formalized. However, all radiocarbon dates obtained from the Farmdale yielded ages of 22,000 to 28,000 years, and all values from the Iowan were "greater than". Therefore, Ruhe et al. (1957, 1959) proposed that the Iowan was older than the Farmdale.

Based on a drilling transect conducted by Ruhe, it was ultimately decided that the Iowan Drift does not exist. Rather, the Iowan is an erosional surface cut into older tills. This work revealed that the Iowan Surface was the result of massive upland erosion during the Wisconsin glacial (Ruhe, et al., 1968; Hallberg, et al., 1978). Continued research by Hallberg et al. (1978) focused on understanding the mechanisms responsible for the formation of the Iowan Erosion Surface. Due to the lack of relief in this landform region, exposures are not especially common. Therefore, most of the work completed has relied on the use of core. Quarry and roadcut exposures were utilized when available.

Description and Materials

It is now understood that the Iowan Surface is the result extensive erosion during the Wisconsin Episode. A period of intense cold from 21,000 and 16,500 years ago and ensuing upland erosion led to the development of the distinctive landform recognized as the Iowan Surface (Prior, 1991). A periglacial environment prevailed during this period with intensive freeze-thaw action, solifluction, strong winds and a host of other periglacial processes (Walters, 1996). The result was that surface soils were removed from the Iowan Surface and the Pre-Illinoian till surface was significantly eroded.

Pre-Illinoian age tills in eastern Iowa and are typically uniform, massive, loam to light clay loam textured, basal tills with associated fluvial deposits and intervening paleosols. However, on the Iowan Surface a combination of weathering and colluvial processes has created a package of much less consolidated materials at the surface. Iowan Surface materials are commonly loamy and sandy sediments, massive to weakly stratified, poorly consolidated, and may contain significant interbedded gravelly or pebbly loam units. There may be up to 20 feet of these materials, and they are commonly thicker on slopes and near stream valleys as part of solifluction lobes related to this time period. Some areas are also overlain by a thin increment (less than 5 feet) of Peoria Formation silt. Due to the nature of these deposits, Erosion Surface materials do not provide the same groundwater protection as an unaltered Pre-Illinoian till would. Oxidized tills and colluviated materials have a much higher hydraulic conductivity than unweathered Pre-Illinoian till deposits.

Geomorphic Features

Characteristic surficial features on the Iowan Surface include a stone line, glacial erratics, ice wedge polygons, and paha. Extensive erosion of the upland stripped material from the surface resulting in the development of a regional colluvial lag deposit, or 'stone line'. Glacial erratics, boulders that have been transported by glaciers from their original depositional position, are commonly seen in this part of the state and are also a remnant deposit. Ice-wedge polygons formed in frozen sediments (permafrost) during this period of intense cold, and subsequently filled with material.

Another common feature of this region are isolated and uneroded topographic highs of loess mantled Pre-Illinoian till, known as paha. These elongated hills are oriented northwest to southeast and are most abundant near the boundary between the Iowan Surface to the north and the Southern Iowa Drift Plain to the south. The stratigraphic units present within a paha are the same as what is typical on the Southern Iowa Drift Plain (oldest to youngest): Pre-Illinoian till, Sangamaon Geosol, Pisgah Formation materials, Farmdale Geosol and Peoria Formation. Surrounding landscapes have had the upper materials eroded and only have Pre-Illinoian materials overlain by weathered or colluviated materials. Good exposures showing the internal stratigraphy of paha are rare, but intensive studies have been completed using drill core.

FIELD TRIP STOPS

Kirkwood Paha

The field trip group will meet on the Kirkwood campus which is located on top of a paha. No exposure is available at this location, but there is a good view of the surrounding Iowan Surface. As we travel to the Hennessey Quarry, we will drive down off the paha and cross the Iowan Surface. Near the Cedar River the elevation will increase as we drive onto a thick pile of Peoria Formation loess likely sourced from the Cedar River. A core description is not available for the Kirkwood paha, however one for the Stanwood paha is presented below as an example of typical stratigraphy for pahas of the area:

Sitename: Zeneshiek (Stanwood Paha)

Location: T-82 N R-03 W section 8 NE1/4
Landscape position: Paha (loess over till)
Parent Material: loess
Soil Series: Seaton
Vegetation: grass
Slope: 7%
Elevation: 1197 ft.
Quadrangle: Stanwood
Date Drilled: 9/7/2004
Described by: Ryan Dermody, Kathy Woida, Deb Quade and Stephanie Tassier-Surine

Landowner: Zeneshiek (Stanwood Paha)
Remarks: 2.7 inch diameter core.
GPS Location:

Depth (ft)	Horizon /W. Zone	Description
		Wisconsin- Peoria Formation-- silt facies
0.0-0.6	Ap	dark brown (10YR 3/2) silt loam; weak fine subangular blocky parting to weak fine granular structure; friable; common fine and very fine roots throughout; common fine dendritic tubular pores; abrupt boundary
0.6-0.9	BE	brown (10YR 4/3) silt loam, dark yellowish brown (10YR 4/4) (dry); weak medium and fine subangular blocky structure; friable; common very fine roots throughout; common fine dendritic pores; 5 percent patchy distinct very dark gray (10YR 3/1), moist, organic stains on surfaces along root channels; clear boundary
0.9-1.8	Bw1	dark yellowish brown (10YR 4/4) silt loam; weak fine subangular blocky structure; friable; 30 percent discontinuous distinct pale brown (10YR 6/3), moist, silt coats on all faces of peds; few very fine roots throughout; common fine dendritic tubular pores; 3 percent patchy distinct very dark gray (10YR 3/1), moist, organic stains on surfaces along root channels; clear boundary
1.8-2.8	Bw2	40 percent yellowish brown (10YR 5/4) and 60 percent dark yellowish brown (10YR 4/4) silt loam; weak medium subangular blocky structure; friable; few very fine roots throughout; 35 percent discontinuous distinct pale brown (10YR 6/3), moist, and light brownish gray (10YR 6/2), moist, silt coats on all faces of peds; clear boundary
2.8-4.0	Bw3	dark yellowish brown (10YR 4/4) silt loam; weak medium subangular blocky structure; friable; few very fine roots throughout; 35 percent discontinuous distinct light brownish gray (10YR 6/2), moist, and pale brown (10YR 6/3), moist, silt coats on all faces of peds; few fine spherical very dark gray (10YR 3/1), moist, manganese masses; clear boundary
4.0-4.9	BC	dark yellowish brown (10YR 4/4) silt loam; moderate medium subangular blocky structure; friable; common fine and medium irregular light brownish gray (10YR 6/2), moist, iron depletions; and common fine spherical very dark gray (10YR 3/1), moist, manganese masses; clear boundary
4.9-6.0	OU	dark yellowish brown (10YR 4/6) silt loam; massive; friable; common fine spherical very dark gray (10YR 3/1), moist, manganese masses; common coarse and medium irregular grayish brown (10YR 5/2), moist, iron depletions; gradual boundary
6.0-7.4	OU	50 percent grayish brown (10YR 5/2) and 50 percent dark yellowish brown (10YR 4/6) silt; massive; friable; gradual boundary

7.4-9.0	OU	olive brown (2.5Y 5/4) silt; massive; friable; common coarse and medium irregular yellowish brown (10YR 5/6), moist, masses of oxidized iron; gradual boundary
9.0-11.2	MOU	50 percent dark yellowish brown (10YR 4/6) and 50 percent olive brown (2.5Y 5/4) silt loam; massive; friable; strongly effervescent; clear boundary
11.2-13.9	MDU	olive brown (2.5Y 5/4) silt loam; common fine faint dark yellowish brown (10YR 4/6) mottles; massive; finely laminated at base; friable; strongly effervescent; abrupt boundary
13.9-17.6	MDU	gray (2.5Y 6/1) silt loam; few very coarse prominent yellowish red (5YR 4/6) and dark reddish brown (2.5YR 3/3) pipestems Fe/Mn; massive; friable; strongly effervescent; abrupt boundary
17.6-18.8	OU	interbedded yellowish brown (10YR 5/6) medium sand and olive brown (2.5Y 5/3) loam; massive; laminated 18.5-19'; very friable; slightly effervescent clear boundary
18.8-21.7	OU	olive brown (2.5Y 5/3) silt loam; few medium to coarse distinct dark reddish brown (5YR 3/4) mottles; massive; friable; sand wedge at 20.6-21.4' (medium sand, yellowish brown 10YR 5/8); slightly effervescent; abrupt wavy boundary
		Farmdale Geosol
21.7-22.5	2ABb	black (2.5Y 2.5/1) and dark gray (2.5Y 4/1) silt loam; massive; friable; noneffervescent; clear boundary
		Farmdale Geosol/Sangamon Geosol
22.5-23.1	2Bwb	dark greenish gray (10Y 4/1) sandy clay loam; moderate very fine granular to subangular blocky structure; friable; noneffervescent; clear boundary
		Sangamon Geosol
23.1-25.0	3Btb	grayish brown (2.5Y 5/2) to olive brown (2.5Y 5/3) clay loam; many fine distinct dark yellowish brown (10YR 4/6) and yellowish red (5YR 4/6) mottles; moderate fine subangular blocky structure; firm; noneffervescent; gradual boundary
		Pre-Illinoian Formation-- Undiff. till
25.0-25.7	MOL	grayish brown (2.5Y 5/2) to olive brown (2.5Y 5/3) clay loam; common fine distinct dark yellowish brown (10YR 4/6) and yellowish red (5YR 4/6) mottles; massive; firm; noneffervescent; missing core 25.7-27'
27.0-29.0	MOL	olive brown (2.5Y 5/3) sandy loam; many medium distinct strong brown (7.5YR 5/6) and strong brown (7.5YR 4/6) mottles; massive; friable; MnO stains common 28-29.5'; noneffervescent; clear boundary; till sediments (glacio-fluvial?)
29.0-31.0	MOL	yellowish brown (10YR 5/6) sandy clay loam; common fine to medium distinct light brownish gray (2.5Y 6/2) mottles; massive; slightly firm; noneffervescent; gradual boundary

31.0-37.0	MOU	light olive gray (5Y 6/2) (upper) to olive brown (2.5Y 5/3) (lower) loam; few coarse prominent dark yellowish brown (10YR 4/6) and strong brown (7.5YR 4/6) mottles; massive; slightly firm; moderately effervescent; gradual boundary
37.0-40.0	MOU2	olive brown (2.5Y 5/3) loam; few medium distinct dark yellowish brown (10YR 4/6) mottles; massive; slightly firm; strongly effervescent

Hennessey Quarry

The Hennessey Quarry is positioned just south of the Cedar River and is located near the boundary between the Southern Iowa Drift Plain and the Iowan Surface. Numerous paha are present along the margin, and outwash from the Des Moines Lobe glacial advance likely provided a source of loess along the Cedar River.

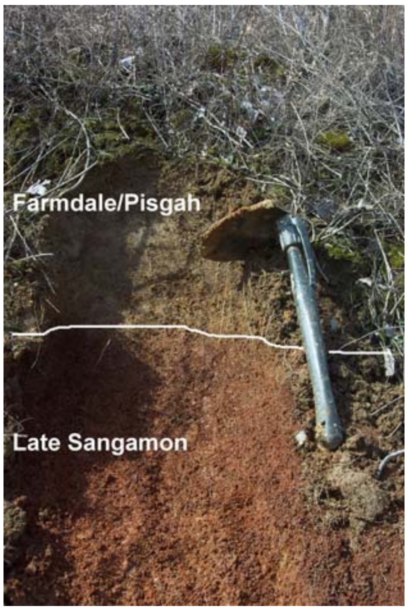
Figure 2: Exposed Quaternary section at Hennessey Quarry. Approximately 70' of Peoria Formation Loess overlies a Late Sangamon Geosol formed in Pre-Illinoian till. A weak Farmdale Geosol and Pisgah Formation materials are also present. Photo by Deb Quade.

The exposure in the quarry provides an excellent look at approximately 70' of Peoria Loess Formation materials (Fig. 2). Thick loess deposits have been noted at several other locations south of the Cedar River in this area (Bettis et al., 1996, 1998, 2005). A very weak and thin Farmdale Geosol and Pisgah Formation are welded onto the Late Sangamon paleosol (Fig. 3a). The paleosol formed in a zone of colluviated or reworked Pre-Illinoian till. These materials overlie loamy oxidized and unleached till materials. Glacial striations are visible on the bedrock bench as a result of cobbles in the till scraping on the bedrock surface as the glacier advanced (Fig. 3b). A brief description of the Quaternary section is provided below. Due to wet conditions at the time of the site visit, the upper portion of the loess section could not be accessed.

Hennessey Quarry- Cedar Rapids, Iowa: Quaternary Description 4/2/2008
(D. Quade and S. Tassier-Surine)

Depth (ft)	Weathering Zone	Description
0-35	OL/U	**Wisconsin- Peoria Formation- silt facies** Section was inaccessible due to wet conditions; materials are assumed to be similar to those below, except that the upper portion is likely leached
35-70	OU	**Wisconsin- Peoria Formation- silt facies** Yellowish brown (10YR 5/4) silt loam, occasional very thin fine sand seams, massive to laminated, friable, strongly effervescent, yellowish brown (10YR 5/6) mottles and manganese accumulations near base, few fine to medium snail shells
70-70.8	2ABb	**Farmdale Geosol** Brown (10YR 4/3) to dark yellowish brown (10YR 4/4) silt loam, massive, friable, non-effervescent, trace charcoal, gradual boundary
70.8-71.3	2Bwb	**Pisgah Formation** Brown (10YR 5/3) to yellowish brown (10YR 5/4) and brown (7.5YR 5/3) heavy silt loam with few fine pebbles, hackly structure, friable, non-effervescent, slopewash or colluvial sediment, gradual boundary- Farmdale and Pisgah welded onto Sangamon below
71.3-72.3	3Bt1b	**Sangamon Geosol (Late Sangamon)** Reddish brown (5YR 4/3 to 4/4) clay loam with common fine pebbles, moderate fine subangular blocky grading to moderate medium subangular blocky structure, friable, non-effervescent, gradual boundary
72.3-73.3	3Bt2b	**Sangamon Geosol (Late Sangamon)** Yellowish red (5YR 4/6) clay loam (more clay than above), strong fine to medium subangular blocky structure, friable, non-effervescent, gradual boundary
73.3-74.3	3Bt3b	**Sangamon Geosol (Late Sangamon)** Yellowish red (5YR 4/6 and 5/6) clay loam with trace fine pebbles, strong medium subangular blocky structure, friable, non-effervescent, gradual boundary
74.3-75.3	3Bt4b	**Sangamon Geosol (Late Sangamon)** Yellowish red (5YR 4/6) and brown (7.5YR 5/4) heavy loam, strong medium to coarse subangular blocky structure, friable, non-effervescent, jointed, gradual boundary
75.3-77.3	OJL	**Pre-Illinoian Till- undifferentiated** Brown (10YR 5/3) to grayish brown (10YR 5/2) loam with common pebbles, massive, friable, non-effervescent, strong brown (7.5YR 5/6) joints, iron and

		black (7.5YR 2.5/1) manganese accumulations, abrupt boundary, appears to be soliflucted or reworked till
77.3-89.3	OJU	**Pre-Illinoian Till- undifferentiated** Brown (10YR 5/3) to yellowish brown (10YR 5/4) loam with common pebbles, massive, slightly firm, strongly effervescent, yellowish brown (10YR 5/6) along joints, common manganese on joint faces
89.3-		**Devonian Bedrock- Cedar Valley Group or Wapsipinicon Group** Glacial striations present on exposed surfaces



3a

3b

Figure 3a: Farmdale Geosol formed in Pisgah Formation materials welded onto a Late Sangamon Geosol. Photo by Deb Quade.

Figure 3b: Glacial striations on the bedrock surface. Photo by Ray Anderson.

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HYDROGEOLOGY OF PRE-ILLINOIAN TILL IN LINN COUNTY

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Quaternary aquitards are often targeted for placement of contaminants because of exceedingly slow groundwater flow velocities. However, few hydrology studies have investigated glacial till older than Illinoian time (> 300,000 BP) despite these older tills overlying a large portion of North America. Compared to Wisconsin-age deposits, little attention has been given to characterizing the hydrogeology pre-Illinoian aquitards. Recently, stratigraphic and hydrogeologic studies were completed at the I-380 pre-Illinoian till hydrology site in southern Linn County Iowa. The study site is located at a rest stop for Interstate I-380 between Iowa City and Cedar Rapids.

In the late 1980's, hydrologic investigations were initiated at the site and at another site in central Iowa as part of a statewide Aquitard Hydrology Project funded by the Iowa state legislature. The eastern Iowa (EI) site was chosen for investigation because the site is located on a thick, pre-Illinoian age till plain without significant loess cover. Previous investigations at the I-380 till hydrology site were led by the U.S. Geological Survey. In 1991, data collection at the Eastern Iowa site was halted due to funding constraints and the monitoring site was essentially abandoned. In 2002, staff from the INDR-Geological Survey resumed hydrologic investigation at the till hydrology site.

An 8-well and 6-well monitoring well nest were installed into a 31 m thick Pre-Illinoian till sequence typical of eastern Iowa (Fig. 1). The upper 1.5 m was oxidized and leached of carbonates (OL) with a weak soil profile (BA horizon) developed in the surface. The OL zone was underlain by 12.2 m of yellowish-brown (10YR5/6) oxidized and unleached (OU) silty clay

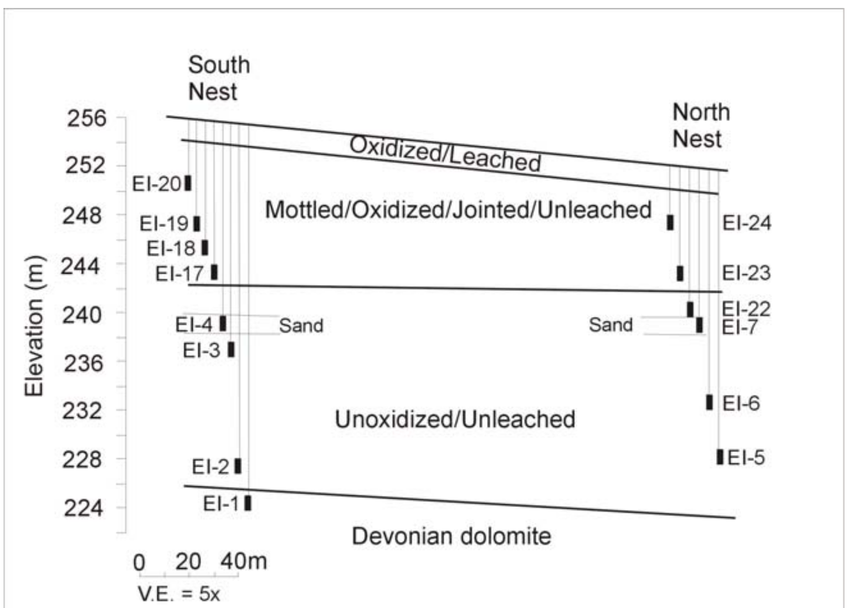

Figure 1. Cross-section of monitoring well network at the I-380 Rest Stop site.

loam with common light gray mottles (2.5Y 6/2). The OU till was fractured and jointed with Fe and Mn accumulations common on joint faces. Very dark gray (5Y 3/1), unoxidized and unleached (UU) silt loam occurred from the base of the oxidized till to the bedrock surface at 31 m. Three sand zones within the till were identified in the EI-2 core (7 to 9 m, 13.1 to 14 m, and 14.6 to 15.8 m), but it is unclear whether the sand units are continuous across the site. Grain size data collected from previous site drilling indicate relative uniformity of texture within the till unit. From 32 soil samples collected from a depth of 2.2 m to 28.6 m, the till averages (and standard deviation) 19.2% clay (2.3), 18.2% fine silt (2.8), 18.9% coarse silt (3.0) and 43.7% sand (3.0). Based on the uniformity of the till (color, texture, consistency, etc.) and lack of weathering zones identified, it is thought that only one till unit is present at the EI site. Although not conclusively identified without clay mineralogy, the till is likely an undifferentiated member of the Wolf Creek Formation.

The water table depth in 2002 averaged approximately 2.2 m and 1.8 m at the southern and northern well nests, respectively, typical of water table conditions for the area. Groundwater occurs under unconfined conditions in the till and under confined conditions in the Devonian bedrock aquifer and in an inter-till sand at the north nest. The potentiometric surface of the bedrock aquifer is approximately 5-10 m above the top of the bedrock surface. Vertical hydraulic gradients were downward from the water table to the Devonian bedrock aquifer at both well nest sites, averaging approximately 0.95 downward. However, within the till section, variation in hydraulic gradient was evident. At the south well nest, most of the total head loss in the till section appeared to occur at the base of the till section between the unoxidized till and Devonian bedrock contact. We hypothesized that the head difference between the till and bedrock aquifer represents an underdrain phenomena, where groundwater in the unoxidized till was drained to the Devonian aquifer faster than recharge through the till replenished it. At the north well nest, an upward hydraulic head was measured from the sand lense to the ground surface and a downward hydraulic gradient was maintained from the sand unit through the unoxidized till.

The hydraulic conductivity (K) of the till decreases substantially from oxidized to unoxidized till. Oxidized Pre-Illinoian till had a K ranging from 8×10^{-8} m/s to 5×10^{-7} m/s with a geometric mean of 1.2×10^{-7} m/s. In contrast, K measured in four unoxidized till wells ranged from 3×10^{-9} to 2×10^{-10} m/s with a geometric mean of 4.5×10^{-10} m/s, a mean more than two orders of magnitude lower than oxidized and fractured till.

The average linear velocity (V) of groundwater through Pre-Illinoian till was calculated using Darcy's Law:

$$\mathbf{V = - Ki/n}$$

where K and i are field measured hydraulic conductivity and hydraulic gradient of oxidized and unoxidized till and n is porosity. A porosity of 0.3 was assumed for Pre-Illinoian till consistent with laboratory-measured values. Primarily due to differences in K, the vertical groundwater velocity in the oxidized portion of the till was much higher than the groundwater velocity in the unoxidized zone. At the south nest, the average downward groundwater velocity through oxidized till was calculated to be 0.38 m/yr based the geometric mean K of oxidized till, average i of 0.03 and estimated n of 0.3. The estimated groundwater age at the base of the oxidized till at the south nest was approximately 34 years.

In the unoxidized till, the vertical groundwater velocity was estimated to range from 0.004 to 0.057 m/yr. From the thickness of unoxidized till at both well nests (approximately 17 m), the estimated groundwater age at the base of the till ranged from approximately 3,950 years to 298 years under vertical hydraulic gradients ranging from 0.1 and 1.2, respectively. The differences in estimated groundwater age at the base of oxidized and unoxidized till suggest that groundwater circulation through oxidized and fractured till is more active and reflects relatively recent recharge (<50 years) whereas groundwater flow through unoxidized till is much slower and reflects recharge centuries to millennia old.

In addition to traditional hydrogeologic methods, environmental isotopes of hydrogen (2H, 3H) and oxygen (18O) and occurrence of nitrate-nitrogen in groundwater provided constraints on groundwater flow velocities estimated with Darcy's Law. Tritium data from the south nest suggested that groundwater at a depth of 9.1 m was recharged less than 50 years ago, representing a velocity of about 0.2 m/yr. This velocity estimate is similar to that calculated for oxidized till from hydraulic data. At the north nest, the upward hydraulic gradient measured in the oxidized till appeared to be retarding downward groundwater transport of tritium in recharge water.

Stable isotope concentrations ranged from –6.2 to –7.9‰ for 18O and from –38.0 to –50.9‰ for 2H and averaged -6.7‰ and -42.3‰, respectively, and plotted on a local meteoric water line (LMWL). Stable isotope profiles indicated a shift toward less negative 18O values with depth with most of the shift in isotopic composition occurring within the upper 10 m of the oxidized till zone. Interestingly, the isotopic composition of modern recharge inferred from water table values is about 1 per mil more negative compared to unoxidized till water, which suggests that modern recharge may be isotopically different than recharge occurring centuries to millennia ago. The shift toward less negative 18O values with depth may suggest a climate change signal contained in the till water but more data are needed to verify this trend.

Occurrence of nitrate-nitrogen (nitrate) in wells is often used as a proxy for identification of groundwater zones vulnerable to recent contamination. In the Pre-Illinoian till water, nitrate concentrations were detected in three samples at the south nest at depths less than 9.1 m. The concentration profile decreased with depth and followed the same depth profile as tritium. Both nitrate and tritium decreased below detectable concentrations between 9.1 and 11.6 m in the oxidized till. Nitrate was not detected in shallow groundwater at the north nest.

Implications for Aquifer Protection by Pre-Illinoian Till

Groundwater velocity determinations derived from hydraulic measurements and isotopic and chemical sampling indicates that Pre-Illinoian till is comprised of two distinct groundwater zones. The upper oxidized zone above 11.5 m is a zone of recent groundwater recharge (<30 to 50 years old). Groundwater flow velocity in oxidized Pre-Illinoian till was estimated to range from 0.2 to 0.4 m/yr. In contrast, the groundwater age of water in unoxidized Pre-Illinoian till may be on the order of centuries to millennia old with flow velocities ranging from 0.4 to 5.7 cm/yr. Thus, protection of underlying bedrock aquifers from surficial contamination in Pre-Illinoian landscapes must be dependent upon the thickness of unoxidized zone if protection for periods longer than 50 years is required.

The thickness and extent of unoxidized Pre-Illinoian till in Linn County was assessed by examining lithologic logs from the Iowa Geological Survey's Geosam database (http://gsbdata.igsb.uiowa.edu/geosam/) for the township area (93.2 km2) of Linn County that contained the study site. Logs were selected for analysis if the driller noted the depth of the contact between oxidized and unoxidized till (often described by a color difference). Significant linear relations were developed relating the unoxidized till thickness to bedrock depth and total till thickness (Fig. 2). Results indicated that unoxidized till did not occur at sites where the bedrock depth was less than approximately 12 m or where the total till thickness did not exceed 15 m. The thickness of oxidized till determined in this manner was very similar to conditions measured at the study site. We estimated the thickness of unoxidized Pre-Illinoian till in Linn County by subtracting the bedrock surface from the land surface elevation in a geographic information system (GIS) and using the relation of unoxidized till thickness to bedrock depth. The thickness of unoxidized till in Linn County was then contoured using the estimated velocity of 5.7 cm/yr. A map of Linn County was produced that showed the estimated vertical travel time through the unoxidized till to the bedrock aquifer (Fig. 3). Any bedrock area overlain by less than 12 m of overburden material was considered vulnerable to contamination with vertical travel times less than 50 years.

Private well nitrate results from shallow bedrock wells from Linn County were plotted on the travel time map (Fig. 3). The results indicated a close relationship between vulnerable bedrock aquifer regions and the absence of substantial thickness of unoxidized Pre-Illinoian till. Nitrate concentrations in excess of drinking water standards were clustered in regions with little or no unoxidized till cover. Likewise, water supply wells were protected from surficial contamination in thick unoxidized till zones in Linn County.

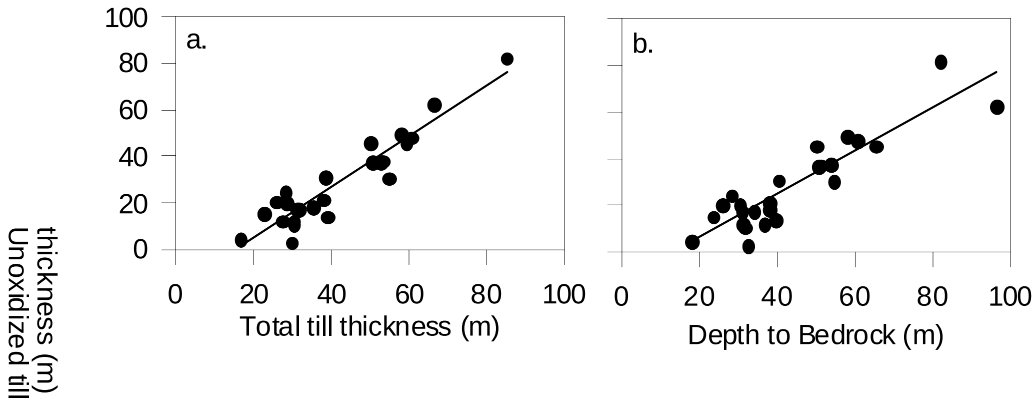

Figure 2. Relation of total till thickness and depth to bedrock with unoxidized till thickness.

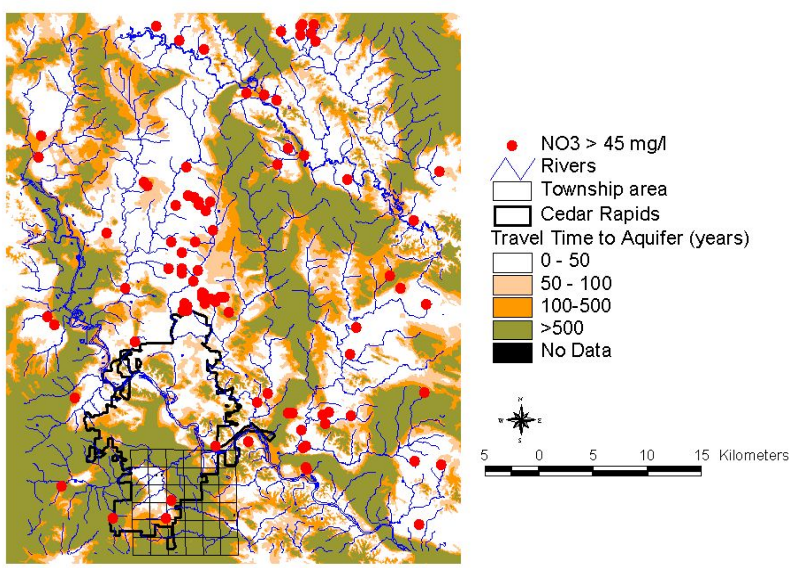

Figure 3. Estimated vertical travel time from the ground surface to bedrock aquifer in Linn County. Nitrate concentrations detected greater than 45 mg/l in private wells are shown.

This material was largely excerpted from the following two publications:

Schilling, K.E. and S. Tassier-Surine. 2006. Hydrogeology of Pre-Illinoian Till at the I-380 Rest Stop Site, Linn County. Iowa Geological Survey Technical Information Series 51, 53 p.

Schilling, K.E. and S. Tassier-Surine. 2006. Groundwater flow and velocity in a 500 ka Pre-Illinoian till, Eastern Iowa. Environmental Geology, 50:1255-1264. DOI 10.1007/s00254-006-0299-9.

Figure 1. Satellite view of the Bruening Rock Products Hennessey Quarry from Google Earth showing the three areas where trip participants will examine geologic features.

DEVONIAN GEOLOGY OF THE BRUENING ROCK PRODUCTS HENNESSEY QUARRY, CEDAR RAPIDS, IOWA

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INTRODUCTION

The first known exploration in the area of the Hennessey Quarry was a test core drilled by the B.L. Anderson Company in 1956. The core, probably drilled on the northeast edge of the property, penetrated 36 feet of loess before encountering Kenwood shales at the bedrock surface. The core passed through 4.5 feet of Kenwood, about 23 feet of "Otis" carbonates, and 6 feet of "Coggon" dolomite, before bottoming about 2 feet into the Silurian Gower Formation. A quarry was opened and changed ownership several times before being acquired by Bruening Rock Products, Inc. As the quarry expanded to the southwest, it encountered increasing younger geologic strata, and now the quarry includes the entire Wapsipinicon Group section and a bit of the overlying Cedar Valley Formation.

REGIONAL GEOLOGY

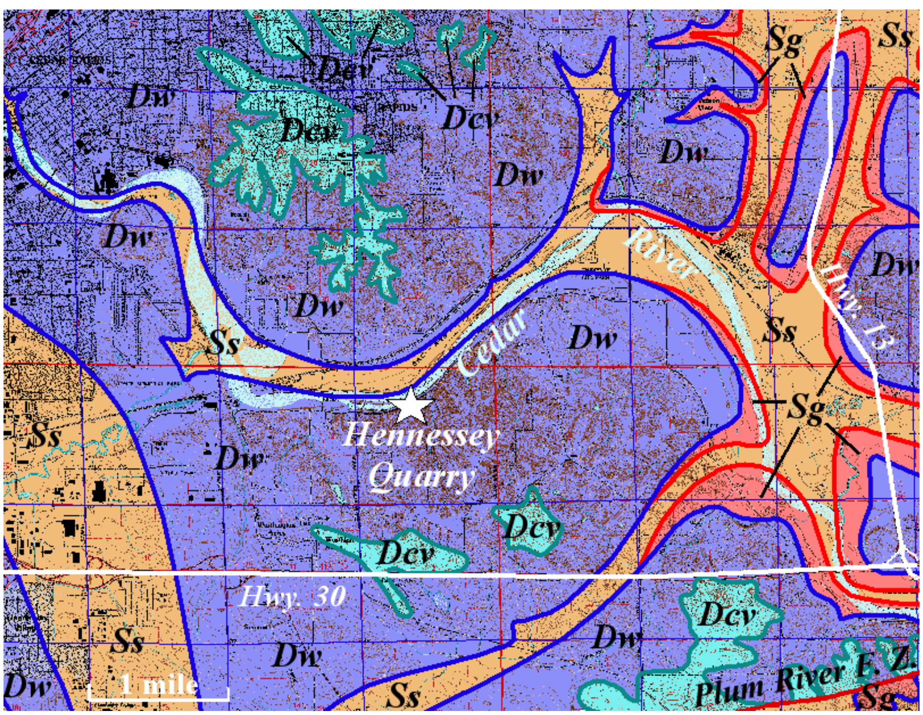

Figure 2. Bedrock Geology in the southeast Linn County field trip area. Dcv =Cedar Valley Group, Dw=Wapsipinicon Group, Sg=Gower Formation, Ss= Scotch Grove Formation. (unpublished geologic map by Brian Witzke, Iowa Geological Survey)

The bedrock over most of the field trip area north of the Plum River Fault Zone in southeast Linn County, Iowa, is Devonian limestone-dominated strata (Fig. 2). The Wapsipinicon Group is the most commonly encountered the bedrock unit, with some areas preserving limestones of the overlying Cedar Valley Group. Numerous bedrock channels in the area cut through the Devonian strata into underlying Silurian dolomites. Both the Gower Formation and the underlying Scotch Grove Formation are exposed in these channels. The significant unconformity that developed on the Silurian surface prior to Devonian deposition removed most of the Gower Formation strata in many portions of the field trip area, leading to deposition of basal Devonian rocks directly onto the Scotch Grove Fm. (Fig. 2).

Plum River Fault Zone

The Hennessey Quarry is located about 2 miles north of the Plum River Fault Zone, a major structural feature that uplifted stratigraphic units south of the fault (Bunker and others, 1985). This stratigraphic displacement can be observed at the Cedar Rapids Quarry just south of the fault zone (Fig. 3) where the Silurian Gower, Scotch Grove, Hopkinton, and underlying strata are

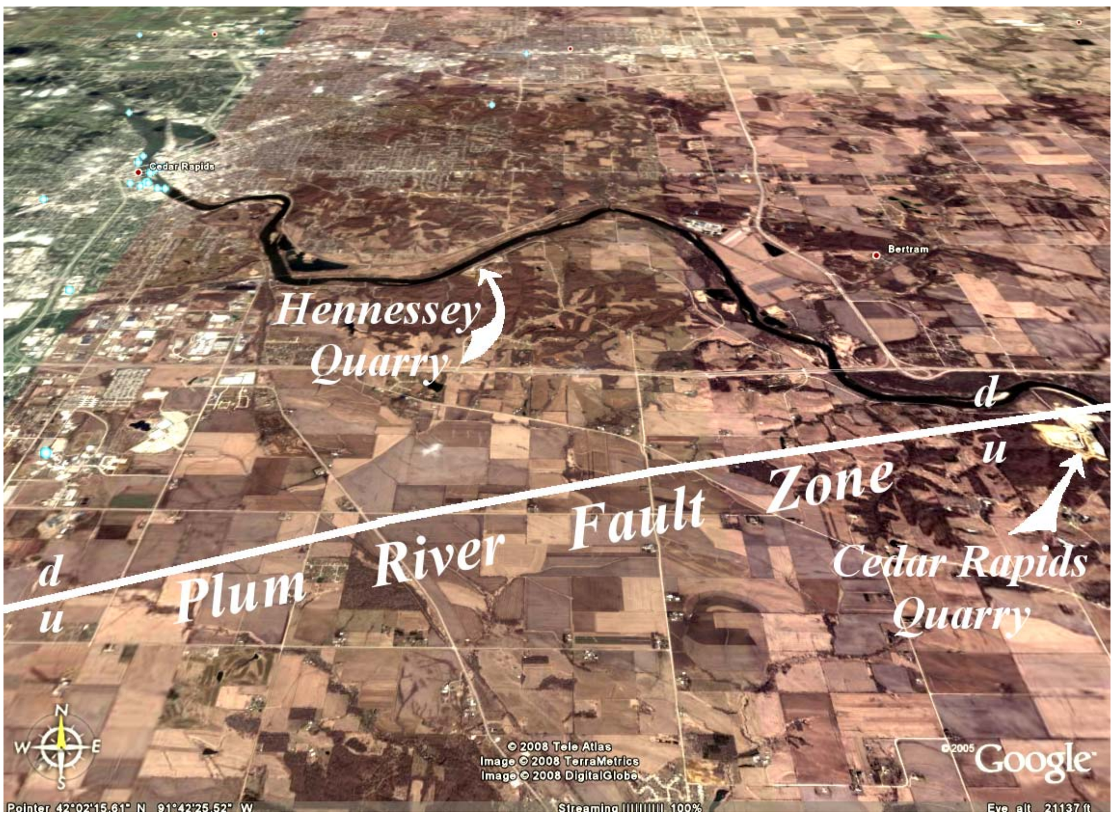

Figure 3. Satellite view of part of southeast Iowa from Google Earth showing the location of the Plum River Fault Zone and the Hennessey and Cedar Rapids quarries.

extracted (Witzke and Anderson, 2005), or exposures of Silurian Scotch Grove Formation at Palisade-Kepler State Park just east of the Cedar Rapids Quarry (Witzke, 1999). Stratigraphic displacement along the Plum River Fault Zone in southeastern Linn County exceeds 250 feet within the Devonian.

STRATIGRAPHY OF THE WAPSIPINICON GROUP

(modified from Witzke and Bunker, 2006a-see reference for additional figures)

Introduction

The Wapsipinicon Group (Middle Devonian) overlies a deeply eroded megasequence boundary (Sloss's Tippecanoe-Kaskaskia cratonic unconformity) in eastern Iowa, where it is known to unconformably overlie Silurian (Gower, Scotch Grove, Hopkinton-Blanding formations) and Ordovician units (Maquoketa Formation, Galena Group). The general stratigraphy of the group has been considered by previous workers, and an overview is provided by Bunker et al. (1985) and Witzke et al. (1988). Studies by Church (1967) and Sammis (1978) further characterize the Wapsipinicon lithofacies of eastern Iowa. Reference sections for the Buffalo Quarry (Witzke et al., 1985) and the Iowa City area (Conklin and Klein quarries (Fig. 4), see also Witzke et al., 1999) provide additional information. The strata of the Wapsipinicon Group are economically important for eastern Iowa providing high quality aggregate and gypsum resources. Stratigraphic nomenclature within the Wapsipinicon Group was modified by Witzke et al. (1988) who recognized the succession, in ascending order: Bertram Formation, Otis Formation, and Pinicon Ridge Formation (Kenwood, Spring Grove, Davenport members).

The age of the Wapsipinicon Group is difficult to constrain because of the general paucity of biostratigraphically useful fossils. The basal Bertram Formation overlies an unconformity on Silurian strata, and it has not yielded any fossils. Bertram deposition is likely allied with the overlying Otis Formation, possibly associated with rising base levels associated with Otis marine transgression (Witzke et al., 1988). The Otis Formation has yielded an impoverished conodont fauna consisting only of *Ozarkodina raaschi*; the species is well represented in the Spillville Formation of northern Iowa, whose conodont faunas indicate an upper Eifelian to basal Givetian age (Klapper and Barrick, 1983). The Otis Formation of southeastern Iowa is apparently correlative with the Spillville Formation and is considered to be the same age. Zonally significant miospores from the Otis Formation agree with this age assignment (Klug, 1994). With the exception of Klug's (1994) miospore study of the Wapsipinicon Group, no other biostratigraphically significant fossils are known from higher strata of the group. The miospores generally support a Givetian age for the Pinicon Ridge Formation (Klug, 1994). The Wapsipinicon Group is constrained above by basal Cedar Valley strata which contain conodonts of the middle *varcus* subzone (mid Givetian age). Therefore, the Pinicon Ridge Formation appears to be a lower Givetian unit by its stratigraphic position.

Otis Formation

The Otis Formation occupies areas of Iowa and adjoining Illinois, and its southern margin stretches across the northern part of southeastern Iowa in Johnson, Muscatine and Scott counties (Bunker et al., 1985). It oversteps the Bertram Formation, and the Otis unconformably overlies an eroded Silurian surface across most of its extent. The Otis Formation is characterized by carbonate strata comprising a succession of shallow-marine, restricted-marine, and peritidal facies. In Linn County the formation has been subdivided into two members (Bunker et al., 1985; Witzke et al., 1988): the lower **Coggon Member**, an interval of dolomite, vuggy in part, with scattered molds of brachiopods (*Emanuella*), gastropods, rostroconchs, and trilobites; and an upper **Cedar Rapids Member** of limestone and dolomite, including sparsely fossiliferous dolomite and limestone (*Emanuella*, gastropods, bryozoans), pelletal limestone (locally with spirorbids), locally oolitic limestone, laminated peritidal carbonates (in part with stromatolites, "birdseye," and mudcracks), and intraclastic to brecciated units (Sammis, 1978). Southward in Johnson, Cedar and northern Muscatine counties the Otis Formation is entirely dolomitized, where a similar succession of depositional facies and faunas is observed. Of note, a bed with abundant molds of solitary and colonial rugose corals is developed at the Moscow Quarry.

Eastward into eastern Muscatine and Scott counties, and adjoining areas of Illinois, the Otis Formation is represented entirely by limestone facies, where it is much easier to observe primary depositional fabrics and fossil content. The formation ranges between about 5 and 8 m thick in this area. Representative sections from this area are shown for the IPSCO and Buffalo Quarry cores. A variety of limestone facies are observed in this area, including: 1) skeletal, skeletal-intraclastic, and peloidal-skeletal pack-grainstones and mud-wackestones containing low-diversity faunas of brachiopods (primarily *Emanuella*), gastropods, rostroconchs, ostracodes, rare echinoderm grains, and stromatoporoids (small stromatoporoids in lower Otis strata in the IPSCO core represent a new fossil occurrence for the formation); 2) peloidal and peloidal-intraclastic pack-grainstones; 3) coated-grain to oolitic pack-grainstones, locally oncolitic; 4) laminated mudstones and stromatolitic units; 5) fenestral limestones ("birdseye" bearing).

The Otis Formation is the only stratigraphic unit of the Wapsipinicon Group in southeastern Iowa that contains normal marine fauna in some beds, including brachiopods, trilobites, corals, and stromatoporoids. Its deposition was limited geographically to a paleoembayment in eastern Iowa and northwestern Illinois, and the Otis marine transgression into this area during the late Eifelian marked the first incursion of Devonian seas into eastern Iowa (Witzke et al., 1988). The Otis correlates with the Spillville Formation of northern Iowa, which contains marine fauna throughout most of the interval, and contains more open-marine facies and more diverse faunas than the Otis (Day and Koch, 1994). This suggests that the initial Devonian transgression proceeded from the north or northeast, with a major southern barrier (the Sangamon Arch) separating marine Eifelian deposition of southern Illinois from shallower and more restricted deposition of the Otis Formation (ibid.). Otis strata of eastern Iowa were interpreted to record a general shallowing-upward depositional sequence (cycle) by Witzke et al. (1988). The presence of peritidal facies (including laminated and fenestral limestones) in the middle part of the Otis succession suggests that the Otis cycle can be further subdivided into two subcycles (Otis T-R cycles 1 and 2 of Day, 2006).

An episode of erosion and karstification separated Otis and Kenwood deposition in the area, and this is reflected by the infilling of Kenwood shale across an irregular karstic surface developed on the upper Otis (see Day, Allied Quarry, this guidebook). At many localities, the upper Otis displays fractures and solutional openings that are infilled with pods and partings of shale and dolomite that resemble lithologies of the overlying Kenwood Member. These include argillaceous dolomite, gray shale (part silty to sandy) and green shale, as well as calcite void fills, and such fillings are seen to occur up to 3 m below the base of the overlying Kenwood Member (as in a core drilled at the Iowa Geological Survey's Oakdale Research facility and Core Library).

Pinicon Ridge Formation

Kenwood Member

The Kenwood Member is the basal unit of the Pinicon Ridge Formation. It oversteps the edge of the Otis Formation, and it unconformably overlies eroded Ordovician and Silurian strata across most of its extent (Iowa, northeast Missouri, northwestern Illinois). The Kenwood Member (also called the Kenwood Shale) is dominated by unfossiliferous argillaceous to shaley dolomite, in part silty to sandy, with lesser interbeds of gray to green shale, in part silty to sandy. Silt and sand grains are composed of quartz and chert. Some dolomite beds are irregularly laminated to mottled. Intraclastic and brecciated beds are common. Concretionary masses of chalcedony and chert are seen in many sections, and some dolomite beds are siliceous. The Kenwood Member includes gypsum and anhydrite evaporite units at localities in southeastern Iowa, and economic gypsum deposits are extracted from the upper Kenwood in subsurface mines near Sperry, Iowa (Sperry Mine section, Fig. 2). Nodular, mosaic, and bedded gypsum-anhydrite are identified, especially in the upper part (Giraud, 1986), and gypsum-anhydrite nodules and stringers are known to interstratify with dolomite beds in the lower part. Where evaporite facies are absent in southeastern Iowa, correlative breccia intervals are recognized, most notably in the upper part of the member (dashed correlations, Fig. 2). These breccias are interpreted to have formed by solution-collapse of interbedded carbonate-evaporite strata, recording the presence of formerly widespread evaporite units within the member. Gypsum crystal molds are locally observed within the upper Kenwood breccias (Fig. 1).

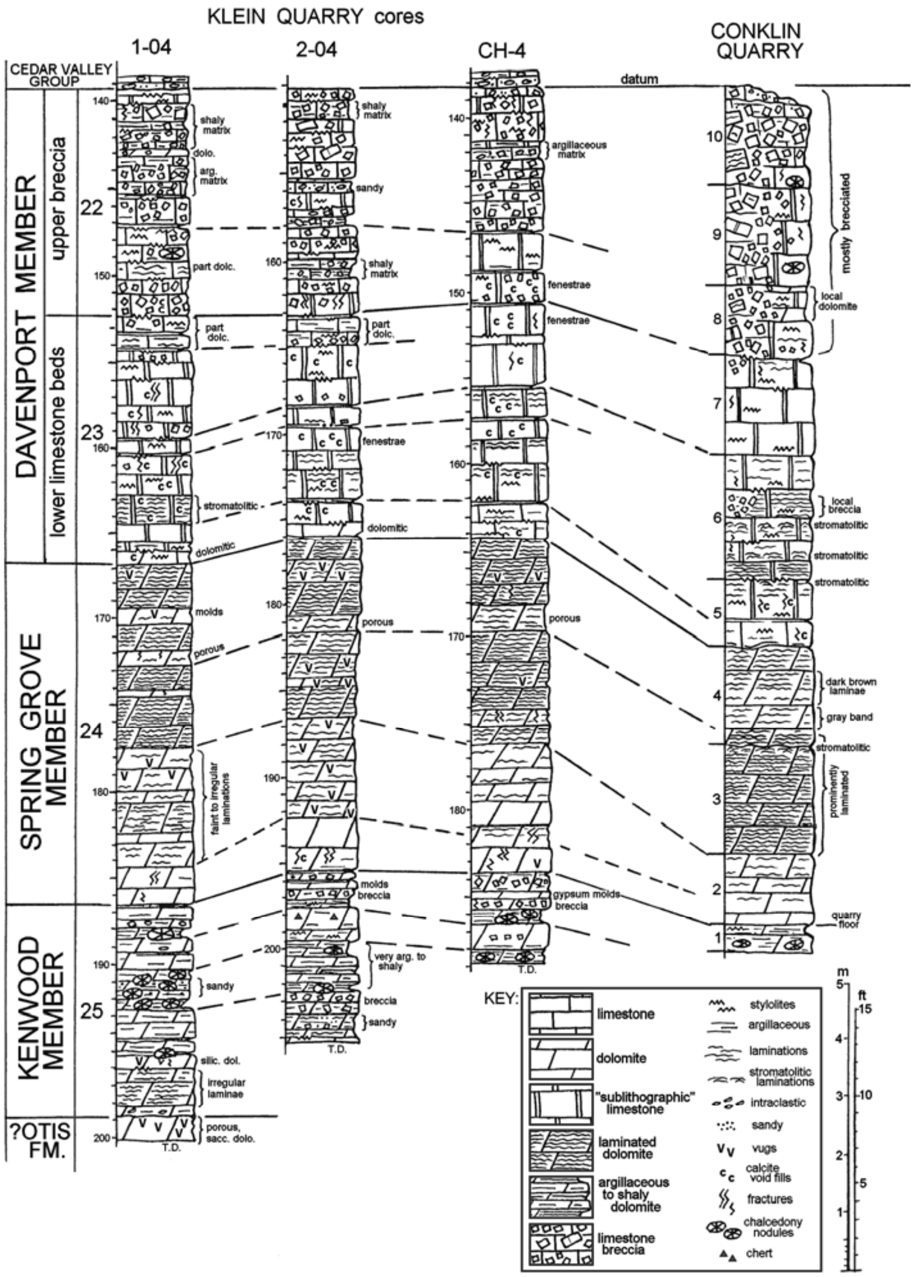

Figure 4. Graphic stratigraphic sections, Wapsipinicon Group, Johnson County, Iowa. Closely spaced core sections from the Klein Quarry are shown to illustrate lithologic variations within the constituent members over short lateral distances (<1 km). Conklin Quarry section adapted from Witzke et al. (1999). Cores stored at the Iowa Geological Survey; core depths in feet.

The Kenwood Member lacks evidence of marine biota, and burrow fabrics are also absent in most beds. Possible burrow fabrics and stromatolitic laminations at a few localities are the only evidence of possible benthic biota in the member. Klug (1994) recovered undiagnostic miospores from the Kenwood. The general absence of benthic fauna and the presence of evaporite units and evaporite collapse breccias suggest a highly restricted environment of deposition, certainly hypersaline at times, and probably with elevated salinities through much or all of its deposition. Even though the Kenwood shows significant geographic expansion over the Otis Formation, a unit that includes marine limestone facies, the Kenwood lacks normal marine facies and faunas. This suggests that the basin of deposition had marginal circulatory barriers which restricted open marine circulation and promoted widespread hypersalinity through net evaporation over a broad area (Witzke et al., 1988). The widespread continuity of the upper Kenwood evaporite and equivalent collapse breccias is interpreted to reflect overall depositional shallowing and increasing hypersalinity in the restricted basin, and the Kenwood is interpreted to represent a general transgressive-regressive (T-R) depositional sequence (Witzke et al., 1988).

Spring Grove and Davenport Members

The Spring Grove and Davenport members of the Pinicon Ridge Formation are considered collectively, as they are interpreted to represent part of the same T-R depositional sequence. In Linn and Johnson counties, the lower Spring Grove Member is dominated by laminated petroliferous dolomite strata, whereas the overlying Davenport Member is characterized by limestone strata with collapse breccias (especially in the upper part). Elsewhere in southeastern Iowa and parts of northern Iowa the distinction between limestone and dolomite strata is less distinct. In fact, the stratigraphic position that separates limestone and dolomite facies in southeastern Iowa varies significantly, and Spring Grove strata locally include limestone facies, and Davenport strata are variably dolomitic in some sections. Except where coincident with the shift from dolomite to limestone, the boundary between the Spring Grove and Davenport members is gradational and arbitrary. The limestone-dolomite facies boundary within the succession is interpreted to be a diagenetic facies transition and not a primary depositional feature. The Spring Grove-Davenport interval is recognized over a broad area of eastern, northern, central, and southern Iowa, and it is known to extend into adjoining areas of southern Minnesota, northern Missouri, and western Illinois (Witzke et al., 1988). The interval generally overlies the Kenwood Member, possibly disconformably, but it unconformably overlies Ordovician or Silurian strata where the Kenwood Member is locally absent (especially above Silurian paleoescarpments).

Typical Spring Grove dolomite strata are dominated by thinly-laminated dolomite facies, and the laminated units are petroliferous to varying degrees, producing a distinctive fetid odor when freshly broken. The organic-rich carbonaceous laminations are brown to black in color in unoxidized sections. The thin horizontal laminations, typically marked by alternations in organic content and dolomite crystal size, are often seen to be laterally continuous. Some crenulated to domal laminations are probably stromatolitic in origin (Fig. 4). The Spring Grove dolomites are porous to vuggy to varying degrees. Some units within the member are only faintly laminated, and non-laminated vuggy dolomite beds are also observed. The member appears to be generally unfossiliferous, but burrows, stromatolites, ostracodes, indeterminate medusoid forms, and placoderms have been noted (Witzke et al., 1988; Hickerson, 1994), the latter two groups noted from a single locality (Milan Quarry, Illinois). Minor breccias and intraclastic units are seen at some localities. Giraud (1986) observed nodular to mosaic anhydrite in the Spring Grove within evaporite-bearing Wapsipinicon successions in southeastern Iowa, and gypsum-anhydrite void fills are also noted locally.

The laterally continuous laminations and general absence of desiccation features within the Spring Grove Member at most localities was interpreted by Sammis (1978) to support deposition in a subtidal setting within a restricted basin of elevated salinity. However, Hickerson (1994) observed a prominent desiccation surface exhibiting large polygonal cracks in the upper 50 cm of the Spring Grove at the Milan Quarry, as well as a disconformity that separates upper and lower strata. He also interpreted upper Spring Grove deposition to include peritidal/supratidal environments, based on his discovery of a local desiccation surface. As such, the Spring Grove succession may represent a general shallowing-upward T-R cycle.

Hickerson's (1994) remarkable discoveries of ptycodontid placoderm skeletons (bitumen impregnated) in the upper Spring Grove and a possible arthrodire placoderm cranium in the lower Spring Grove at the Milan Quarry are particularly enlightening. Although the Spring Grove Member is largely devoid of macrofauna, these discoveries indicate that certain fish taxa were capable of living in the shallow restricted environments of Spring Grove deposition, at least at times.

The Davenport Member derives its name from exposures of upper Wapsipinicon Group strata in the Davenport area. Sammis (1978, p. 163) designated the Buffalo Quarry as a surface reference section for the member, but no type locality has ever been formally designated. It is proposed here that the natural exposure along Duck Creek at Devil's Glen Park in the eastern part of the Quad Cities area be designated the type locality for the member. The Davenport section at that locality exposes about 7 m of laminated to brecciated limestone strata above more massive beds of Spring Grove dolomite strata.

The Davenport Member is dominated by limestone across most of its extent, primarily characterized by dense 'sublithographic' limestone, laminated to stromatolitic in part, and with common stylolites. The term 'sublithographic' refers to the resemblance to limestones used in lithographic engraving, and these dense lime mudstones often break with a conchoidal fracture. The Davenport limestones are dominantly mudstones, but pelletal and intraclastic units are also commonly present. Rare oolitic packstone-grainstone beds are noted. A few limestone beds display calcite-filled fenestral and 'birdseye' fabrics and gypsum crystal molds. Scattered chalcedony concretions are recognized locally. Although the member is dominated by limestone, discontinuous and local dolomite and dolomitic limestone beds are recognized at a number of localities. Thin shales (in part silty to sandy) and argillaceous to shaley units are observed in many sections. The Davenport Member is dominated by evaporite facies in some areas of southeastern Iowa, where nodular, mosaic, and massive gypsum-anhydrite units are observed to interbed with limestone and dolomite strata (Giraud, 1986).

The Davenport Member is best known for its well developed limestone breccias, a characteristic feature in most sections across its geographic extent. These breccias consist of irregular unsorted angular clasts of limestone (varying in size from a few millimeters to large blocks in excess of 1 meter diameter) generally in a limestone to argillaceous limestone matrix. The Davenport breccias have been interpreted to have formed by solution-collapse processes (Sammis, 1978). This process results from the dissolution of evaporite layers causing the fracturing and internal collapse of intervening carbonate beds. Most breccia clasts consist of lithologies seen within the Davenport Member, primarily sublithographic and laminated limestone. However, the upper breccias also contain scattered fossiliferous limestone clasts derived from overlying strata of the Solon Member.

The Davenport Member can be divided into upper and lower units across much of its extent in southeastern Iowa. The lower interval consists predominantly of sublithographic limestone beds, commonly laminated to stromatolitic. Breccias are locally present, but they are subordinate to the bedded limestone strata. By contrast, the upper interval contains abundant limestone breccias, and breccias form the dominant lithology at many localities. Nevertheless, breccia units are replaced laterally by bedded limestone units at some localities, and the upper interval, although brecciated in part, is dominated by bedded limestones in the Quad Cities area.

Except for an abundance of stromatolitic laminations in the Davenport limestones, the member is mostly unfossiliferous. Burrows and ostracodes are noted in some beds, but skeletal macrofauna is entirely absent in the member. The absence of a flourishing benthic biota suggests a stressed, probably hypersaline, environment of deposition for the Davenport. The presence of evaporites and evaporite solution-collapse breccias in the member underscores the hypersaline nature of Davenport deposition. Some Davenport strata were deposited in subaequeous environments, particularly the pelletal and oolitic units. Limestone facies that display continuous laminations, similar to those seen in the Spring Grove, and some of the evaporite units were also likely deposited in subtidal settings, possibly within a salinity stratified sea (Sammis, 1978; Witzke et al., 1988). However, the presence of fenestral limestones and desiccation surfaces within the Davenport Member indicates that peritidal/supratidal facies were part of the depositional mosaic. In general, the Davenport-Spring Grove forms a generalized shallowing-upward succession, with an overall upward increase in supratidal and evaporitic facies.

Prior to initial transgression of the Cedar Valley seaway, "Davenport strata were subaerially exposed and subjected to freshwater diagenesis" (Sammis, 1978, p. 226), and there is evidence for minor erosional relief on the upper Davenport surface. Evaporite solution-collapse was likely initiated during this episode of subaerial exposure and freshwater diagenesis. However, the incorporation of fossiliferous clasts derived from the Solon Member within the upper Davenport breccias indicates that solution collapse brecciation continued coincident with early Cedar Valley deposition. The incursion of the Cedar Valley seaway with waters of normal-marine salinity could also result in the dissolution of Wapsipinicon evaporites, as normal seawater, as with freshwater, is undersatured with respect to gypsum. The contemporaneity of evaporite solution with early Cedar Valley deposition is best illustrated at sections in Benton County and northward, where Solon strata are extensively brecciated in places (the upper part of the so-called "Fayette Breccia"), most likely related to the ongoing collapse of underlying evaporite units within the Davenport Member

WAPSIPINICON GROUP ROCKS IN THE HENNESSEY QUARRY

NOTE: THE HIGH WALLS IN THE QUARRY ARE VERY UNSTABLE AND VERY DANGEROUS. STAY BACK FROM THE QUARRY WALLS

Otis Formation

Coggon Member

The Coggon Member, basal unit in the Otis Formation, is exposed just along the road from the area of the scale house to the entrance of the main part of the Hennessey Quarry. Within the quarry the Coggon can be found in rare exposures in the quarry floor. In this field trip we will examine the Coggon near the base of the ramp that leads to the bedrock bench ((2) on Fig. 1). At this location (Fig. 5) the Coggon is a yellow-brown vuggy dolomite with scattered molds of small brachiopods

Cedar Rapids Member

Lying conformably above the Coggon Member, the Cedar Rapids Member of the Otis Formation is a complex suite of limestone and dolomite beds. Nearly the entire thickness of the Cedar Rapids Member can be viewed in the quarry (Fig 6), with only the very basal strata obscured beneath the quarry floor. The Coggon-Cedar Rapids contact is readily observable in exposures in the haul road cut near base of the ramp that leads to the bedrock bench (Fig. 6). Just above the contact numerous stromatolites can be observed (Fig. 7), confirming the shallow water depositional environment for the unit as described in Witzke and Bunker (2006). Calcite mineralization can be observed in lenses within the Cedar Rapids Member. These lenses, first described by Norton (1895) include sandstones and other unusual lithologies including black carbonaceous material (Fig. 8). These areas of unusual lithologies and mineralization are probably karst fills, similar to those seen at the top of the Cedar Rapids Member, at its contact

Figure 5. Exposures of the Coggon Member of the Otis Formation and its contact with the overlying Cedar Rapids Member on the south wall of the haul road cut leading into the Hennessey Quarry, (2) on Figure 1.

Figure 6. Exposures of the Otis Formation and Pinicon Ridge Formation strata in the Hennessey Quarry, (1) on Figure 1.

Figure 7. Stromatolites near the base of the Cedar Rapids Member (Otis Formation) on the south wall of the haul road cut leading into the Hennessey Quarry, (2) on Figure 1

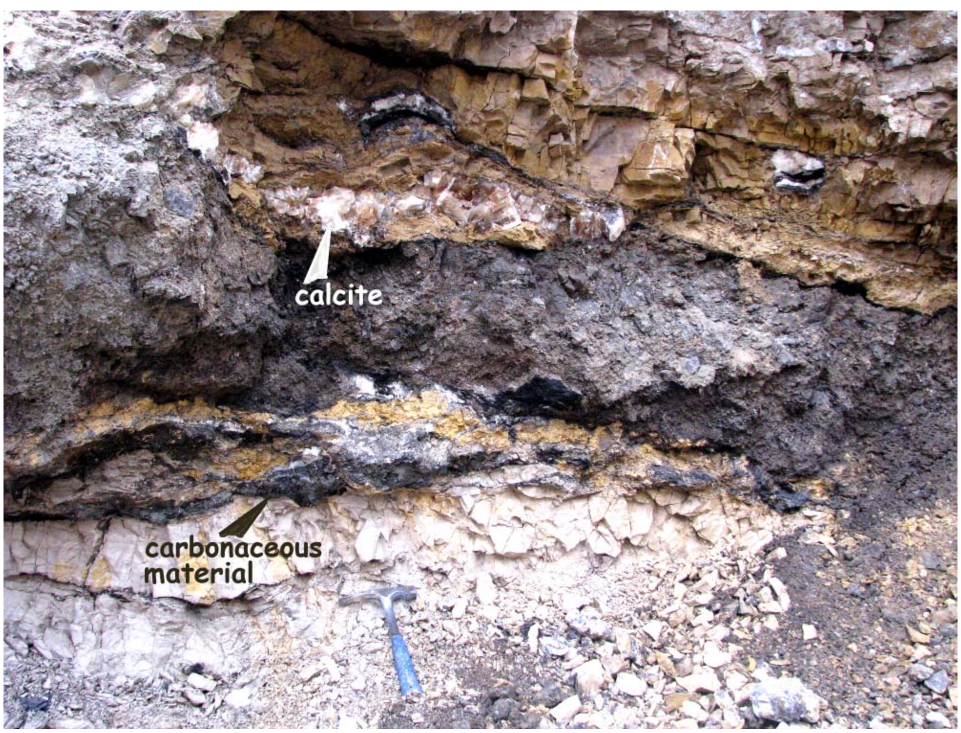

Figure 8. Calcite-filled pod in the Cedar Rapids Member with other unusual lithologies including carbonaceous material, south wall in Hennessey Quarry, (1) on Figure 1

with the Kenwood Member of the Pinicon Ridge Formation. One of these lenses is observable near the east edge of the south wall of the Hennessey Quarry.

Pinicon Ridge Formation

Kenwood Member

The Kenwood Member (also called the Kenwood Shale) of the Pinicon Ridge Formation includes a wide variety of lithologies, textures, and colors, but is dominated by unfossiliferous argillaceous to shaley dolomite, in part silty to sandy, with lesser interbeds of gray to green shale, in part silty to sandy. Silt and sand grains are composed of quartz and chert. Some dolomite beds are irregularly laminated to mottled. Intraclastic and brecciated beds are common. Chalcedony nodules are also seen in the Kenwood, apparently replacing evaporates.

The Kenwood Member is not directly accessible at the Hennessey Quarry, but a wide variety of Kenwood lithologies are available in rock piles on the quarry floor. One large boulder of

Figure 9. Shaley Kenwood Member boulder on the Hennesey Quarry floor, with a white chert bed and adjacent brown sandy unit preserving mud cracks.

of Kenwood Member strata on the floor of he quarry (Fig. 9) includes a bed of chert associated with a brown sandy bed that displays mud crack structures, indicating a depositional up direction.

Spring Grove Member

The Spring Grove Member lies unconformably above the Kenwood Member (Figs. 4 & 6), and its upper contact with the Davenport is also marked by an unconformity. Spring Grove strata are dolomites, dominated by thinly-laminated dolomite facies, and the laminated units are petroliferous to varying degrees, producing a distinctive fetid odor when freshly broken. The organic-rich carbonaceous laminations are brown to black in color in unoxidized sections. The thin horizontal laminations are typically marked by alternations in organic content and dolomite crystal size and are often laterally continuous. Some crenulated to domal laminations are probably stromatolitic in origin. Brecciation can also be observed in some beds. The Spring Grove dolomites are porous to vuggy to varying degrees. Some units within the member are only faintly laminated or non-laminated and may be vuggy . The Spring Grove is generally unfossiliferous, but burrows, stromatolites, ostracodes, indeterminate medusoid forms, and placoderms have been noted.

Davenport Member

The uppermost visible geologic unit in the Hennessey Quarry is the upper member of the Pinicon Ridge Formation, the Davenport Member (Figs. 4 & 6). In this area the unit is characterized by brecciation, with blocks consisting of irregular unsorted angular clasts of limestone (varying in size from a few millimeters to large blocks in excess of 1 meter diameter), primarily sublithographic and laminated limestone, frequently stromatolitic. The brecciation that we see at this quarry is primarily the product of the dissolution evaporitic units that were initially

Figure 10. Two large blocks of Davenport Member (Pinicon Ridge Formation) breccia on the Hennessey Quarry floor.

deposited near the base of the Davenport, however similar evaporates also formerly existed elsewhere in the unit. While the unit is not directly accessible, many blocks of the unit can be found on the quarry floor (Fig. 10) and in rock stockpiles. These breccias consist of irregular unsorted angular clasts of limestone (varying in size from a few millimeters to large blocks in excess of 1 meter diameter) in a limestone to argillaceous limestone matrix. The brecciation in the Davenport member has been interpreted as the product of collapse due to dissolution of underlying evaporate beds (Sammis, 1978). Fossils associated with the overlying Solon Member (Little Cedar Formation) are found within the breccia matrix near the top of the Davenport section, suggesting brecciation contemporaneous with deposition of Little Cedar sediments.

CEDAR VALLEY GROUP ROCKS IN THE HENNESSEY QUARRY

NOTE: THE HIGH WALLS IN THE QUARRY ARE VERY UNSTABLE AND VERY DANGEROUS. STAY WELL AWAY FROM HIGHWLL EDGE

The Cedar Valley Group of Iowa consists of four formations, each corresponding to a large-scale transgressive-regressive (T-R) depositional sequence and each deposited during a cyclic rise and fall of sea level. In ascending order, these include the Little Cedar, Coralville, Lithograph City, and Shell Rock formations. A revised stratigraphic framework for these strata, encompassing new stratigraphic nomenclature and improved correlations, was proposed by Witzke and others (1988), and the reader is referred to that reference for definitions and interpretations of the constituent formations and members of the Cedar Valley Group (Witzke and Bunker, 2006b).

Little Cedar Formation

The Little Cedar Formation, the basal unit in the Cedar Valley Group, is comprised of three members, (from the base up) the Solon, Rapid, Bassett, Eagle Center, and Hinkle members.

Solon Member

The Solon Member forms the basal interval of the Little Cedar Formation in southeastern Iowa. The lower Solon rocks exposed at the Hennessey Quarry are characterized by slightly argillaceous fossiliferous limestone (wackestone and packstone) with a diverse marine fauna (brachiopods, crinoid debris, bryozoans, etc.).

Boulders of Solon Member strata can be found on the floor of the Hennessey Quarry (Fig. 11) and as a thin erosional remnant on the bedrock bench above the quarry (Fig. 12). On the bedrock bench, the Solon Member contains abundant brachiopods, many of which can be seen in section on the glacial striated surfaces. IGS geologist Brian Witzke collected a variety of brachiopods from the Solon at the quarry. Table 1 lists the brachiopods he identified.

Note : Basal Cedar Valley Strata and Fossils (Devonian), Hennessey Quarry, Linn County, Iowa by Brian J. Witzke, Iowa Geological Survey

The highest bedrock strata exposed at the Hennessey Quarry include a few feet of the basal Cedar Valley Group, Little Cedar Formation, Solon Member (Middle Devonian). These fossiliferous limestone beds disconformably overlie the unfossiliferous and brecciated Davenport Member of the Wapsipinicon Group, and the surface at the top of the Davenport is slightly irregular with up to a foot or so of relief. The basal Solon Member locally displays well developed glacial striations along the upper bench of the Hennessey Quarry.

The basal Solon Member at the quarry and elsewhere in eastern Iowa is characterized by fossiliferous limestone beds with fine skeletal packstone fabrics. Large brachiopod fossils are prominent in places, and a collection of well preserved brachiopod fossils was secured at the quarry. Additional fossils include disarticulated crinoid debris, bryozoans (including trepostomes and fenestellids), auloporid corals, and small cup corals. Some brachiopod shells are partially encrusted with bryozoans or spirorbid worm tubes. The brachiopods belong to the "independensis beds" (Independatrypa independensis Zone) of the lower Solon Member. The brachiopod collections from the Hennessey Quarry are summarized below. The brachiopod fauna is dominated by the large atrypid Independatrypa independensis; the largest specimen is 6 cm across.

Independatrypa independensis - 32 specimens
Pseudoatrypa bremerensis - 11
Spinatrypa mascula - 9
Schizophoria meeki - 15
Orthospirifer iowensis - 11
Tylothyris cf. *T. bimesialis* - 5
Tylothyris sp. – 1
Strophodonta sp. – 1
Pentamerella multicosta - 1

Figure 11. Block of Solon Member (Cedar Valley Formation) limestone on the Hennessey Quarry floor.

Figure 12. Solon Member (Cedar Valley Formation) limestone exposed as a thin erosional remnant on the Hennessey Quarry bedrock bench..

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THE CEDAR RIVER IN EASTERN IOWA

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INTRODUCTION

The Cedar River watershed extends from its headwaters in southern Minnesota to Columbus Junction, Iowa, where it joins the Iowa River and subsequently flows into the Mississippi River. The total drainage area of the Cedar River is 7,815 mi^2, 87% of which is located in Iowa (Iowa Department of Environmental Quality, 1976). When the Cedar River joins the Iowa River in Columbus Junction, the yearly average discharge is 136 m^3/s. This discharge is larger than the Iowa River average of 82 m^3/s. It should be noted that discharges of both rivers vary considerably over time. During flood events overland flow is the main constituent of discharge and during dry events baseflow (groundwater flow) is the primary component of flow. On an annual basis, it is estimated that 96% of the flow is baseflow, and the remaining 4% is surface runoff (Squillace and Endberg, 1998).

There are eight major tributaries to the Cedar River: the Upper Cedar River, Shell Rock River, West Fork Cedar, Beaver Creek, Black Hawk Creek, and Wolf Creek all merge in the Cedar Falls/Waterloo region, and Prairie Creek and Indian Creek connect in the Cedar Rapids area (Fig. 1). In addition to the main tributaries, there are also many smaller, first order streams throughout the watershed (Squillace et al., 1996).

GEOLOGIC SETTING

The oldest bedrock in the Cedar River watershed includes Ordovician-age sandstones and dolostones found in the central part of the watershed, near the city of Cedar Falls, IA. The youngest bedrock includes small areas of Cretaceous-age sandstone scattered throughout the watershed. The most prevalent bedrock in the Cedar River Valley is Silurian and Devonian limestone and dolostone. Both the Ordovician and Silurian-Devonian systems are important aquifers throughout the region. Shallow bedrock, often with Karst features, including caves, sinkholes, and springs, is prevalent in the upper part of the watershed above the city of Cedar Falls.

The major landform regions included in the watershed are the Des Moines Lobe, forming the headwaters of the major tributaries on the western edge of the drainage basin, and the Iowan Surface, located in the middle and east of the drainage basin. The Des Moines Lobe is the youngest landform region in Iowa, formed by glaciation in the Late Wisconsinan period 12,000-15,000 years ago (Prior, 1991). The poorly drained, ‘knob and kettle’ terrain of the Des Moines Lobe was initially marked by many low-lying marshes, sloughs, and wetlands. Surface drainage in the Des Moines Lobe was initially limited because of a lack of an integrated stream network. However, over the past 150 years, man-made drainage basins have been implemented, removing the original wetlands and lowering the water level to provide excellent cropland for mono-agricultural establishments. These man-made structures are typically channelized, high-energy streams that have direct contact with the agricultural landscape via subsurface drain tiles. Row crop agriculture on the Des Moines Lobe has dramatically increased over the past hundred years, increasing from 41% in 1900 to 72% in 1992 (Brown and Jackson, 1999).

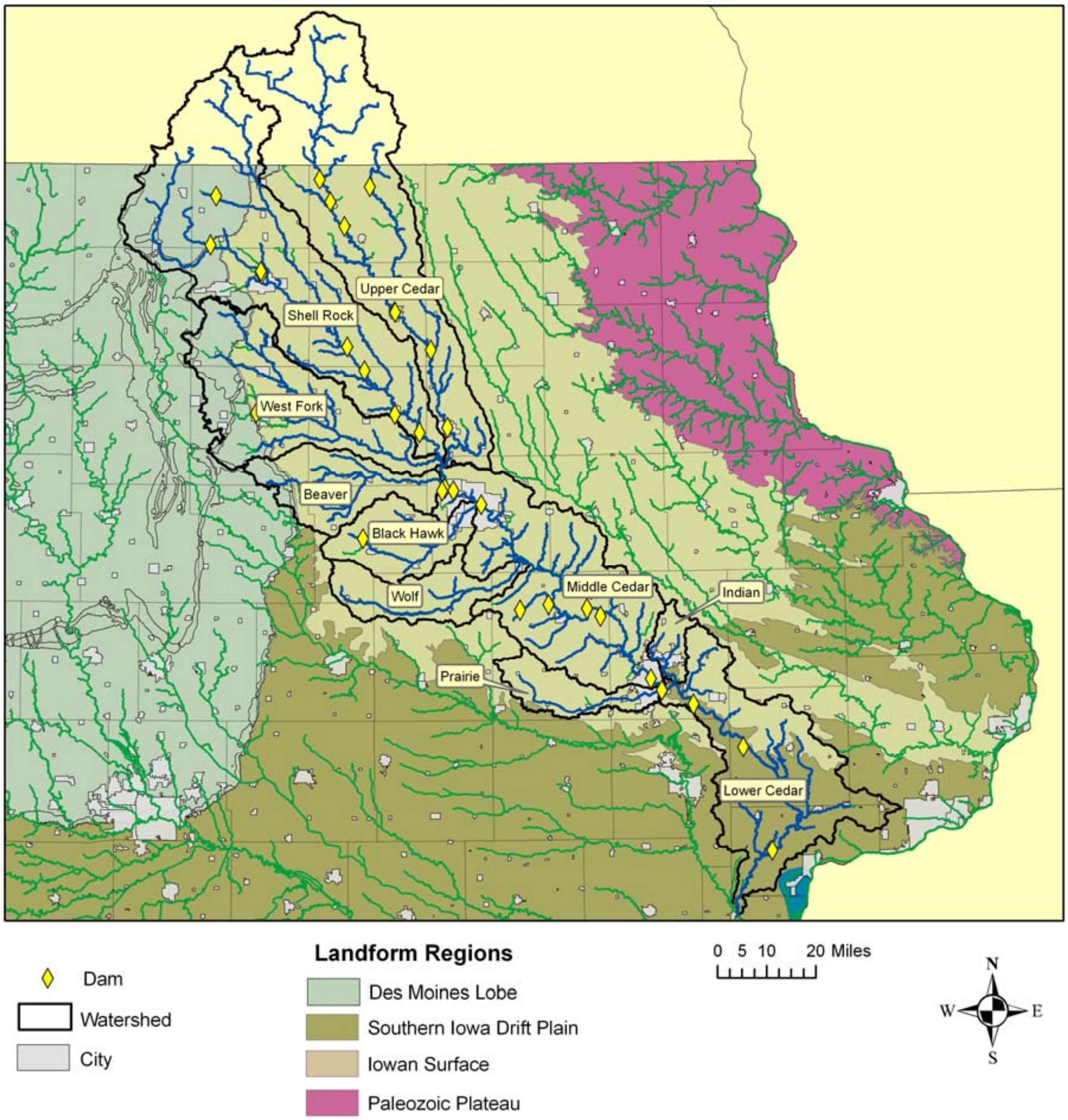

Figure 1. Major landforms, tributaries and sections of the Cedar River.

The central and eastern part of the Cedar River is located on the Iowan Surface, which is characterized by gently rolling landscapes and mature, dendritic drainage patterns. This landscape was initially part of the Southern Iowa Drift Plain, but underwent extensive erosion in Wisconsinan time from 21,000 to 16,500 years ago. Much colder than today, tundra conditions prevailed in these areas around 17,000 years ago. The regular freeze-thaw pattern and turbulent winds eroded the landscape rather dramatically and formed a stone-line or pebble band within the first few feet of the surface. Discontinuous loess deposits lie above these areas in some places, but most loess was blown off the surface by strong winds. Topography in the Iowan Surface tends to be gently rolling, with highly meandering low-gradient streams (Prior, 1991). Rowcrop agriculture dominates 60% of the Iowan Surface (Brown and Jackson, 1999).

Landsat 2002 imagery specifies land use in the Cedar River watershed as predominantly agricultural (81%), with rowcrop agriculture prevailing (73%) (Table 1). The two major crops harvested in the watershed are corn and soybeans. Along with rowcrop agriculture, several confined and unconfined livestock operations are scattered throughout the watershed, including beef and dairy cattle, hogs, sheep, and poultry. There are many major urban establishments located along the Cedar River, including Albert Lea and Austin in Minnesota, and Mason City, Cedar Falls, Waterloo, and Cedar Rapids in Iowa. Many small towns are also scattered throughout the watershed. The 2000 census estimates that of the 516,000 people living within the watershed, 431,000 are within incorporated cities, and 85,000 are located in rural or non-incorporated areas. The watershed includes 125 incorporated communities.

Table 1. 2002 Landsat imagery land use percentage in the Cedar River watershed.

Sub-basin	Area (mi^2)	Rowcrop	Forest	Grassland	Developed	Water	Other
Upper Cedar*	1,441	72.6	4.5	18.0	3.5	0.8	0.5
Shell Rock*	1,756	72.8	2.9	18.7	3.1	2.2	0.3
West Fork	858	77.1	2.9	16.9	2.4	0.6	0.1
Beaver Creek	399	79.8	2.3	15.0	2.5	0.4	0.0
Black Hawk	339	81.2	1.7	12.6	4.2	0.3	0.1
Wolf Creek	333	80.9	2.4	14.3	2.1	0.3	0.0
Middle Cedar	1,223	62.8	7.4	20.9	7.0	1.7	0.2
Total	6,349	72.7	4.0	17.9	3.8	1.2	0.3

*Landsat imagery unavailable for the extreme upper portion of watershed

CEDAR RIVER HISTORY

Western pioneers began settling the Cedar River basin in the late 1830's to 1840's. First known as the "Red Cedar River" due to the many Juniper, or Red Cedar, trees that grew along its banks, the river was noted for its strong, shallow current. This legacy survives today in names of cities that are near the river. In addition to Cedar Falls and Cedar Rapids, Waterloo was originally named *Prairie Rapids Crossing* until 1851. Early pioneers that settled along the river used its strong currents to power saw mills that became the early center for many of the growing towns. William Patterson Harmon of Waverly, William Sturgis of Cedar Falls, and Osgood Shepherd of Cedar Rapids are just a few of the founding pioneers that saw the great potential in using the natural energy of the river. Almost as soon as the first settlements occurred, dams were constructed to control the fast moving water and provide recreation areas and eventually electricity to the local communities (Fig. 2). Today there are over 20 dams located along the main channel of the river, and many more spread throughout the watershed. This equals about one dam every 15 river miles.

Figure 2. An 1895 photograph showing the Cedar River, dam and Mill at Nashua, Iowa.

Over the years, the Cedar River has provided communities and nearby residents with many benefits, including a means of transportation, entertainment, power, water and food. Cedar Rapids residents built the steamer *The Cedar Rapids* in 1858 and used it for round trips to St. Louis. However, a collision on the Mississippi River and the arrival of the railroad ended most commercial means of transportation on the river. Until phased out by cars, local communities had horse races on the frozen river in the winter, and ice houses were prevalent along the river banks. Today, most communities and businesses near the river either directly or indirectly use the river to provide water for public consumption and as a power source. Communities like Cedar Falls and Waverly, and businesses like the Duane Arnold Nuclear Power Plant, use the prominent Silurian-Devonian bedrock aquifer near the Cedar River.

Along with all other rivers in Iowa, the Cedar River's shape and watershed has been greatly influenced by past glaciation events. Many of the headwaters of the major Cedar River tributaries begin in the Des Moines Lobe region before flowing to the Iowan Surface. The Winnebago River shows a close association with the most recent Wisconsinan glaciation, as its current location follows the position of the Altamont readvance for 30 miles before heading east and eventually joining the Shell Rock River. Indeed, most of the western side of the watershed was formed by the Des Moines Lobe features. Past glaciation events may explain the configuration of the river at it's the base near Conesville, as the river flows along the margin of the Illinoian glacial advance. Bedrock topography indicates that the Wapsipinicon River to the east might have flowed into the Cedar at one point, unlike today where it flows directly into the Mississippi River.

CURRENT ISSUES

Like most rivers in Iowa, agricultural practices have had a large impact on both the movement of water and water quality in the Cedar River. Row crop agriculture accounts for most of the land use within the watershed, leading to many nonpoint source pollution issues (Table 1). Headwaters in the Shell Rock, West Fork, and Beaver Creek have undergone extensive tile drainage, which speeds up the movement of water and pollutants to the river. In addition, much of the watershed area above Cedar Falls is in Karst terrain, making the 'natural plumbing' of the upper Cedar River conducive to the quick transport of nonpoint source pollutants.

Although Iowa does not yet have water quality standards for many nonpoint source pollutants, Cedar Rapid's use of the Cedar River for drinking water places it on the Environmental Protection Agency's (EPA) impaired water's list for nitrate pollution. Nitrate levels become a concern at or near the drinking water standard of 10 mg/l as nitrate-nitrogen. The Cedar River and its tributaries consistently have higher averages than are allowed by current EPA drinking level standards (Fig. 3).

In 2006 a study was completed to determine the major sources of nitrate to the Cedar River above Cedar Rapids. The study compared the six upstream major tributaries of the Cedar River to find the major inputs and sources of nitrate pollution. Figure 3 details the estimated contribution of average flow and nitrate load from the headwaters to the Cedar River, along with nitrate-N loads, contributions per unit area, and concentrations from each of the six major tributaries. The results indicate that the Upper Cedar River was the largest contributor of both flow and nitrate to the Cedar River. Interestingly, the Shell Rock River had substantially smaller amounts of nitrate load than discharge would indicate. The decrease in nitrate concentration in the Shell Rock River could be due to a dam located upstream of the gaging and discharge stations. Biological processes such as algal and plant uptake in the dam waters may decrease the amount of nitrate exported from the river. The large discrepancy in load per area for Beaver Creek is due to the smaller flow per unit area than the other streams, although it has one of the higher concentrations (Fig. 3). The smaller load in Beaver Creek is potentially due to the wetland preserves near the mouth of the river. These wetland areas convert nitrate-nitrogen to organic nitrogen and remove the nitrate from the system. Wetlands also evaporate and transpirate much of the water near the surface of the land.

Nitrate is not the only nonpoint source pollution concern in the Cedar River. Sedimentation, turbidity and phosphorus are other environmental issues that need to be addressed soon in Iowa. Currently there is a state wide effort to determine nutrient and sediment standards for lakes and rivers. Many efforts are being made to both quantify and clean up pollution in the Cedar River. IOWATER volunteers regularly check the water quality of chosen sites along the river, including each of the major tributaries. Their work has helped locate spills, point source pollution, and helps compare the different segments of the river. If you would like to become an IOWATER volunteer, please visit the website at www.iowater.net. The Cedar River Environmental Group (CREG) is a group dedicated to "the long term sustainability of the Cedar River and its tributaries". Since 1988, this watershed group has sponsored a volunteer river clean up and more recently a music festival aimed at promoting and encouraging watershed residents to actively take part in the well being of the Cedar River. The website for the group is at www.thecregproject.org.

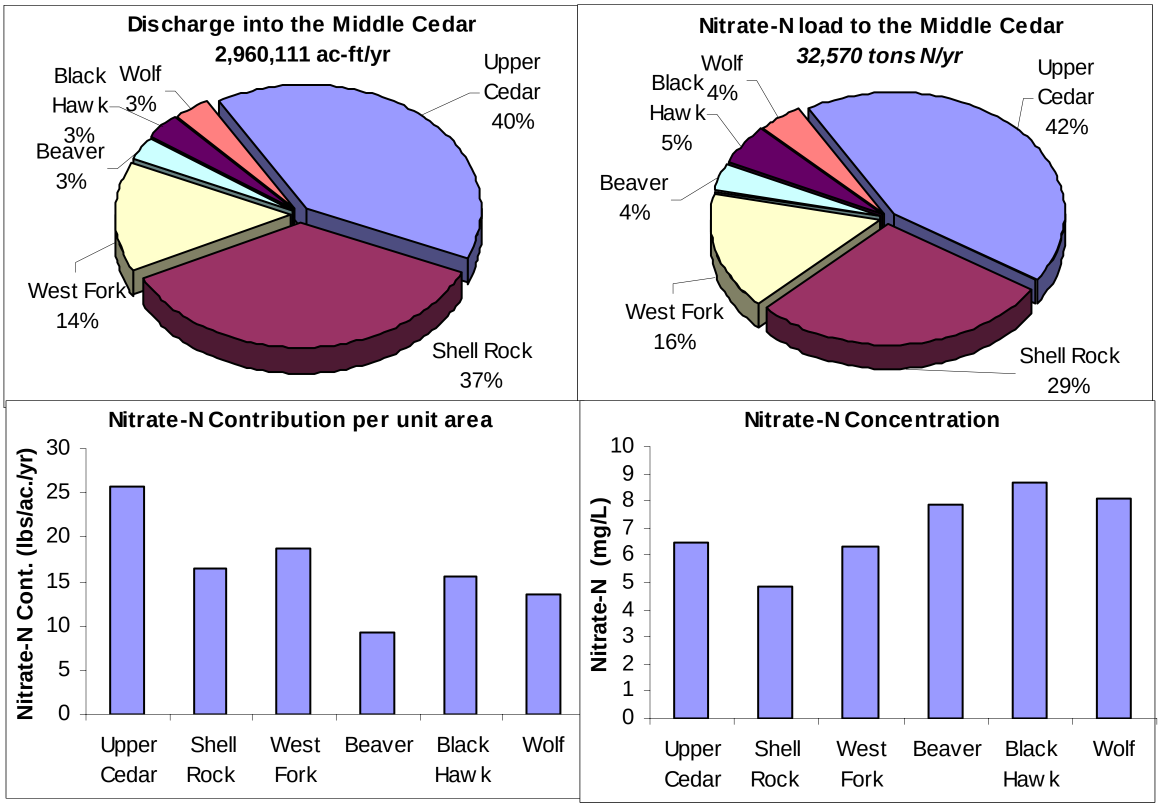

Figure 3. Estimated tributary contribution of flow and nitrate-N to the Middle Cedar (IDNR, 2006).

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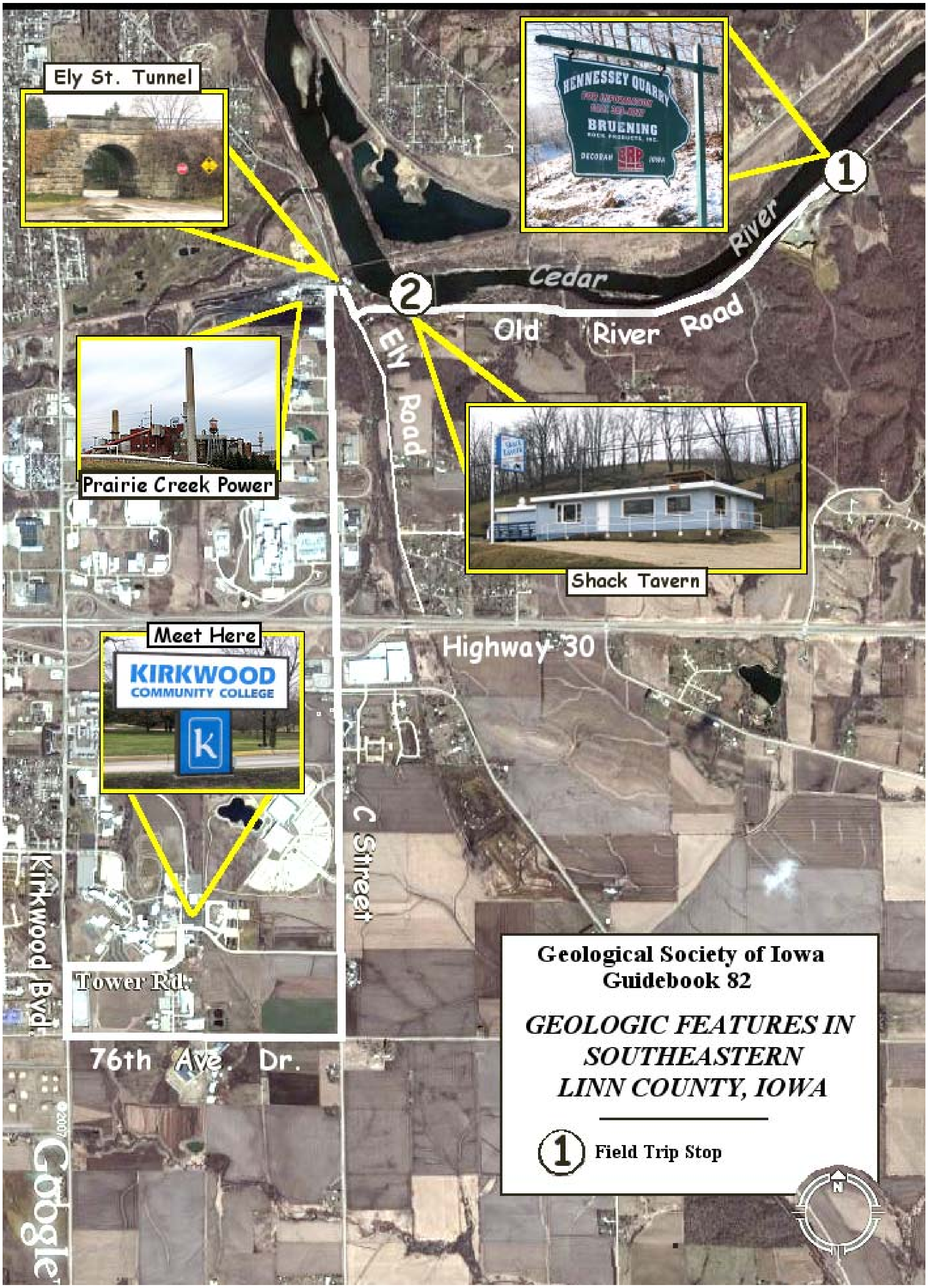
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