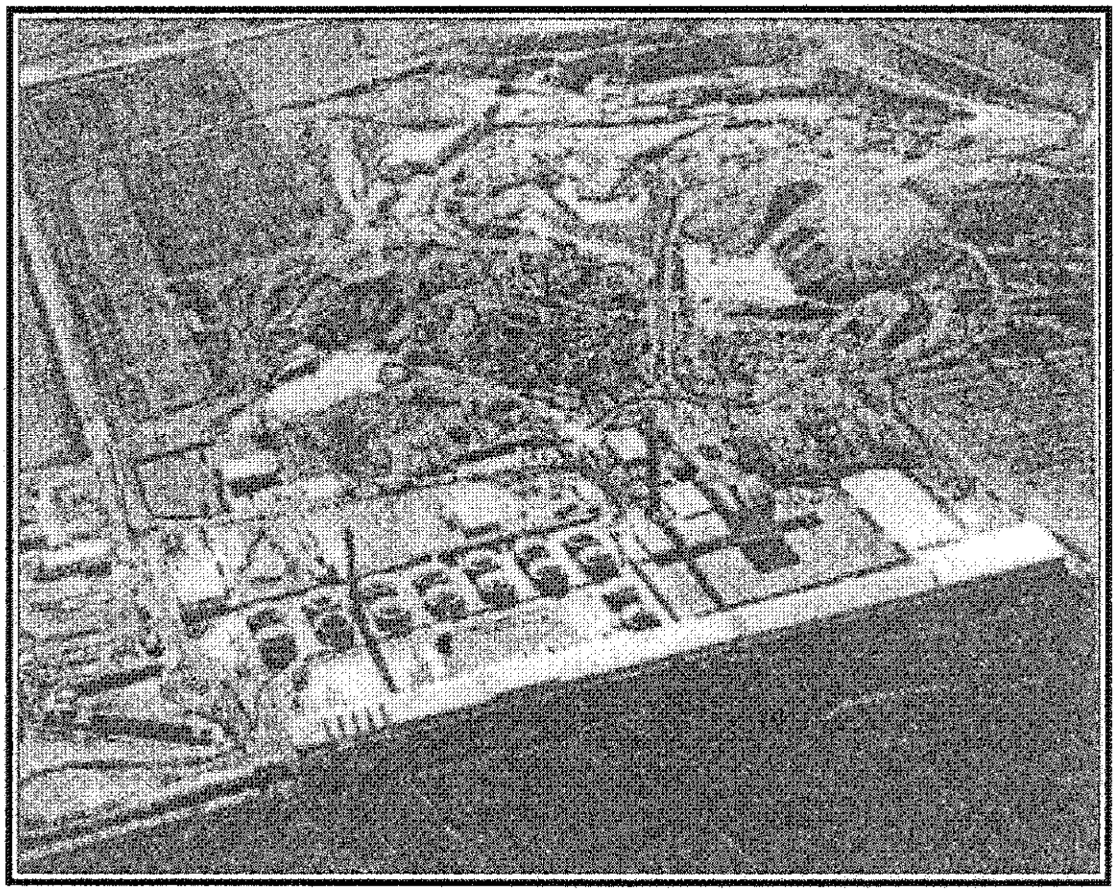
Geology and Hydrogeology of Floyd-Mitchell Counties

North-Central Iowa



GEOLOGICAL SOCIETY OF IOWA

October 28, 1995 Guidebook 62

Cover Photograph: Rockford Brick and Tile in the early 1960s looking south-southwest. The elongate building in the foreground houses tunnel kilns. Sixteen beehive kilns are shown, also. County road B47 is in the upper left corner.

GEOLOGY AND HYDROGEOLOGY OF FLOYD-MITCHELL COUNTIES
NORTH-CENTRAL IOWA

edited by

Bill J. Bunker

October 28, 1995

Geological Society of Iowa
Guidebook 62

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ACKNOWLEDGMENTS

The authors and contributors of this guidebook wish to acknowledge and express our appreciation to the many people and services of north-central and northeast Iowa who have given of their time and effort to allow us to pursue and describe the geologic and hydrologic history of this region. Accessibility to the files and records of the Floyd (Mary Ann Townsend) and Mitchell (Lori Mark) Counties Historical Societies is greatly appreciated. To the landowners (Leroy and Wayne Jones, Lithograph City quarries) who have allowed us access to the varied tasks of our undertakings and property we are deeply indebted. Funding for Floyd and Mitchell counties water quality studies has been supported, in part, through grants from the U.S. Environmental Protection Agency (EPA), Region VII, IDNR EPA Section 319 Program, Floyd County Groundwater Protection Project which has cost shared the closure of the ADWs, and Iowa Department of Agriculture and Land Stewardship (IDALS) Water Quality Protection Funds which is administered through Floyd County Soil and Water Conservation District (SWCD). Water quality analytical work has been provided by the University Hygienic Laboratory (UHL). To the private well owners who have allowed IDNR-GSB access to sample their drinking well water for the ADW Closure Project.

INTRODUCTION

The 1995 Geological Society of Iowa Fall Field Trip takes us to an especially interesting area of Iowa geology, the Floyd-Mitchell County area. The geology of Mitchell County was described in a 1903 Iowa Geological Survey Annual Report, Floyd County is one of four counties in Iowa for which early county geological reports were not produced. The bedrock in this region is dominated by Middle to Upper Devonian carbonate rocks, with two classic areas of exposures to be visited on this trip, the Rockford Brick and Tile Company quarry **(Stop 1)** which exposes the Juniper Hill Shale, Cerro Gordo, and Owen Members , Lime Creek Formation, which yield abundant invertebrate marine fossils, world famous for the diversity, excellent preservation, and ease of collection, and the quarries at Lithograph City **(Stop 2)**, in which limestone beds were so uniformly fine-grained that they were quarried to be etched and used as printing plates in the early part of the century. These lithographic limestones were first described in 1903 by Iowa's first State Geologist, Samuel Calvin, who noted that "One striking feature of the geology of Mitchell county is the extraordinary development of the fine-grained, whitish, lithographic beds which mark a very definite and easily recognized horizon..." We will also have an opportunity to see the carbonate cliffs of the Osage Springs Member, the upper-most member of the Lithographic City Formation, both at our lunch stop at Osage Spring County Park and at its type section, along the Iowa River south of the town of Osage **(Stop 3)**.

In the second half of the trip, we will have a chance to see how the human use of geologic features has led to degradation of the environment and what is being done to remedy these problems. First, we will visit a highly karstified area north of the town of Floyd **(Stop 4)**, and see how humans have used sink holes as dumps, not realizing that these features were pipelines directly into the aquifers that were providing their water. A local conservationist will explain what is being done to clean up this problem. Then we will view giant sand-filled ice wedges **(Stop 5)** that formed in the glacial till at the time when the climate of the region was much like the tundra of northern Canada. These ice wedges, and other features of the paraglacial environment in northern Iowa and a similar environment in Alaska, will be the topic of this evening's banquet talk by Dr. Jim Walters, University of Northern Iowa. Finally we will visit an active agricultural drainage well site, where excess water from farm fields, along with excess nitrogen and agricultural chemicals, is drained directly into underlying aquifers, and a second drainage well that has been properly abandoned and sealed **(Stop 6)**.

STOP 1

GEOLOGY AND HISTORY OF THE ROCKFORD SHALE PIT

THE ROCKFORD AREA: A HISTORICAL PERSPECTIVE

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THE TOWN OF ROCKFORD

Robert James Waller (Rockford High School class of 1957, former Dean of the School of Business at the University of Northern Iowa, and author of the huge best seller — "Bridges of Madison County") described the area near Rockford as follow:

> "Iowa is a very romantic, mystical place. I can't explain it, but it's here. Anyone can see the Rocky Mountains — they're obvious. It takes a little more perspective to see the beauty of Iowa. She just lies there, on hot June days, like a woman in the sun, while romance splashes around where the Winnebago runs to kiss the Shell Rock, just two miles from the place of my growing."

Rockford (1990 population: 863) was founded in 1856. Located between two streams (Shell Rock River and Lime Creek, which later had its name changed to Winnebago River), Rockford provided an excellent site for saw and grain mills. Other businesses were established in due course. In 1864, Dwight Johnson and Harmon Mitchell established a brewery at Rockford that was well received by some, serving Rockfordians as well as residents of several towns within a 40 mile radius. However, pressure from local prohibitionists forced the brewery to close during the early 1880s, and it burned shortly thereafter. ***The Cedar Rapids Republican*** commended the citizens of Rockford for achieving a victory over "saloonism" and predicted that Rockford "will be slow, indeed, to invite the demonstrated curse back again to thrive at the expense of the community's morals and the depletion of its financial savings" (Vala, 1968, p. 56).

The railroad came to Rockford in 1871, and the presence of the railroad was a key factor in Lord Melborne Harris' decision to open a brick operation there. Unfortunately for Harris, the railroad could not be convinced to build a spur to the brick works west of town. Without doubt, the coming of the railroad (the Burlington, Cedar Rapids, and Minnesota Railroad) was responsible for Rockford's rapid growth and transformation in the 1870s. Prior to the arrival of the railroad, Rockford was a tiny farming community with businesses depending on local supply and demand. In 1865, the population of Rockford was about 300. At that time, the town had a church, a school, a flour mill, a saw mill, a river ferry, and a stage line from Cedar Falls. A bridge was built to span the Shell Rock River in 1865 (Vala, 1968).

The population of Rockford reached 400 in 1870 and 700 by 1880. The town had its first newspaper in 1872, a second flour mill in 1873, a new Methodist Church, a new school building valued at $8,000 in 1873-74, a grain elevator, and a new iron bridge across the Shell Rock River in 1875 (Vala, 1968).

The editor of the ***Dubuque Times*** spent three days in Rockford in 1876 and reported favorably concerning the town's location and the operation of its two flour mills. The article noted the presence of a bank, six general merchandise stores, two drug stores, two restaurants, three hardware stores, one furniture store, one harness shop, one boot and shoe shop, one livery stable, two lumber yards, four blacksmith shops, and two wagon shops. The Burlington, Cedar Rapids, and Minnesota Railroad was described as doing "an immense business with the entire Shell Rock Valley". According to the editor of the ***Dubuque Times***, "Much might be said about Rockford, and still there would be room for more, but after three days stay in the place we conclude that a more pleasant town or a more lucrative place for a business situation it would be hard to find" (Vala, 1968, p. 64).

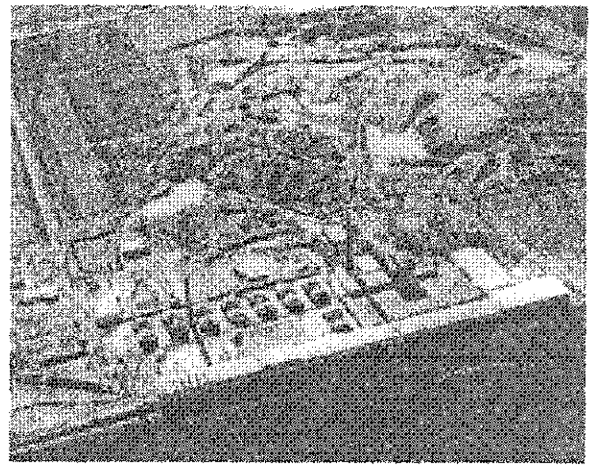
On March 16, 1987, the citizens of Rockford voted in favor of incorporation and elected Orlo H. Lyon as the first mayor. Rockford was the third incorporated town in Floyd County and second only to Charles City in importance (Vala, 1968).

THE ROCKFORD BRICK AND TILE COMPANY

Rockford-area residents knew of the value of the "Rockford clay hills" as early as 1860, and Lord Melborne Harris came from Clarksville in 1878 to establish a brick works on the south banks of Lime Creek. Although his bricks were recognized as some of the finest in the state, Harris could not convince the railroad to build a bridge across Lime Creek and construct a spur of tracks to his kilns (Vala, 1970).

A manufacturer of clay products commented on the situation in an article in ***The Rockford Register*** in 1899: "By the way, I note that Mr. Harris is trying to get a railroad track to his yard. The possibilities for a large business at his clay banks are beyond calculation, and your people should assist him in all ways possible. The one thing all should study and work for is to make work for men. The constant drain upon timber must largely increase the cost of lumber, and clay must come to use for all building purposes. The Lime Creek shales are rare deposits —valuable beyond a possibility of estimation. Your people do not know the value of the deposit near and in your town" (Vala, 1970, p. 230).

The brick works of Harris supplied bricks for several buildings in Rockford, including a number of homes, both bank buildings and most of the store buildings on the north side of Platt Street. Harris also manufactured drainage tile, which had only limited use at the time. His business closed in 1899. During peak production, Harris' operation employed 16 men and produced 24,000 bricks per day. The only means of transporting the finished products to the railroad in town was by horse and wagon (Vala, 1970).

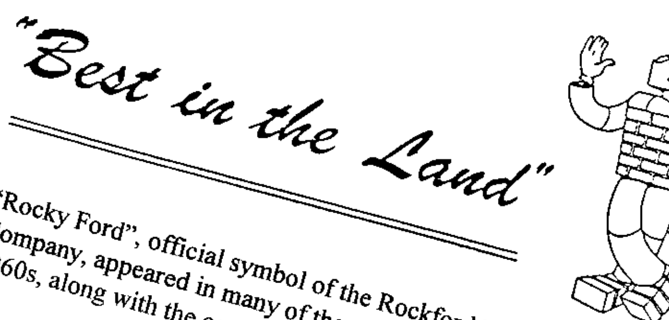


Rockford Brick and Tile Company in the early 1960s looking south-southwest. The elongate building in the foreground houses tunnel kilns. Sixteen beehive kilns are shown, also. County road B47 is in the upper left corner.

An attempt to revive the brick and tile operation by a Mr. Wild of Cedar Falls failed in 1902 when the railroad again declined to lay a spur of track to the plant. In 1909, the railroad closed its shops in Rockford and transferred its employees out of town. That action caught the attention of local citizens and stimulated them to form a local corporation to manufacture brick. The Rockford Brick and Tile corporation was formed in 1910 with \$75,000 in capital stock, and a new plant building was completed in 1911. The corporation spent \$20,000 to construct a bridge and railroad spur. The overall venture was bold and expensive for the times, and it took several years for the corporation to offset its initial heavy debts. In 1914, the plant produced 107 carloads of clay products (Vala, 1970).

The corporation grew steadily through the years, although times were rough during World War I, the Great Depression, and World War II. After World War II, the company concentrated its efforts on the manufacture of drain tile and eventually discontinued manufacturing building tile and face and common brick. In 1961, sales topped the \$1,000,000 mark and production capacity was more than doubled from that of the original plant. Two tunnel

This 1950s-vintage handbill from Rockford Brick and Tile, captures a prevailing view in some quarters that cropland is a more valuable commodity than pasture land. The virtues of clay tile are also extolled.



"Rocky Ford", official symbol of the Rockford Brick and Tile Company, appeared in many of the company's advertisement in the 1960s, along with the company motto: "Best in the Land".

A variety of clay tiles, produced by Rockford Brick and Tile, are illustrated in a company brochure from the 1960s.

kilns were installed in 1961 and two years later, two tunnel-kiln driers were added (Vala, 1970).

Grover H. Galvin, Jr. was president and general manager of the Rockford Brick and Tile Company in 1970, having succeeded his father in 1946. Grover H. Galvin, Sr. had been with the plant almost from the beginning, having been elected manager in 1913. Forest Evashevski of Iowa City was one of the directors of Rockford Brick and Tile in 1970 (Vala, 1970). Sports fans will recognize Evashevski as a former football coach and athletic director at the University of Iowa.

In 1970, Rockford Brick and Tile employed over 50 persons and had eight salesmen in Iowa and Minnesota. The company conducted over $1,000,000 in sales of locally-manufactured drain tile. In addition, Rockford Brick and Tile served as a distributor for several out-of-state brick companies with brick sales in excess of $600,000. According to Vala (1970, p. 235), "Beyond question, the very earth has proved to be Rockford's chief asset, and the Rockford Brick and Tile Company has been not only the town's financial life line over the past 60 years but also a major element in the town's general progress".

The increased use of plastic pipe and tubing in the early 1970's led to the decline of the clay-tile industry. The Rockford Brick and tile grounds were sold to Allied Construction Company of Charles City in 1977. In 1990, the Floyd County Conservation Board obtained the property under Iowa's first Resource Enhancement and Protection (REAP) grant.

CHRONOLOGY OF SELECTED EVENTS RELATED TO THE ROCKFORD BRICK AND TILE OPERATION AND GROUNDS

The following items were obtained from historical files and newspaper clippings at the Rockford Public Library and from copies of the minutes of the Board of Directors Meetings of the Rockford Brick and Tile Company. I am grateful to Rita Hirv, Librarian, Rockford Public Library and Wayne Meyer, former director of the Floyd County Conservation Board, for their assistance. Items are presented in chronological order.

1910 — Rockford Brick and Tile Company is incorporated

1915 approx. — During World War I, a number of Greek nationals are employed at the Rockford Brick and Tile Plant, having come to the United States without their families. They returned to Greece after the war was over.

1941 — A company advertisement promotes the use of Rockford Speedtile for construction of dairy barns: "Build Better Dairy Barns With Rockford Speedtile. They Cost No More And Last As Long As the Farm. Every Day Should Be "DAIRY DAY" In the Rockford Community."

1941 — G.H. Galvin, president and general manager of the Rockford Brick and Tile Company announces a voluntary increase in employees' wages. Men who had been drawing 40 cents per hour were granted an increase to 42 1/2 cents per hour.

1942 approx. — A number of women are hired for the production line during World War II with employment continuing after the war.

1943 — An advertisement in local newspapers promotes the cost effectiveness of Rockford Drain Tile:

"Pays for Itself with One Year's Increased Crops The Best Investment You Can Make! Right Now is the time to install Rockford Drain Tile on your farm and reap the benefits every year — wet or dry. All government restrictions have been removed, so you can buy and use all you need. Rockford Drain Tile is manufactured from ALL SHALE. Thousands of midwest farmers have long acclaimed the superior quality of Rockford Drain Tile and have cashed in on the increased productivity which this tile makes possible."

A shale planer is installed for use in the pit at the Rockford Brick and Tile grounds at a cost of $30,000. "Now three men do the work of many."

1947 — The newly-organized Rockford softball league gets off to a good start at the high-school diamond when the "Clay Diggers", sponsored by Rockford Brick and Tile downed the "Meatchoppers" of the Nissen Locker Plant by a score of 5-3.

1949 The Rockford Brick and Tile Company moved their offices from above the First State Bank to a new office building at the plant site west of town. The new quarters offers "a pleasant view to visitors approaching the plant."

1950s Language of typical advertisements and promotional literature for Rockford Drainage Tile advocates a strong preference for development of cropland as opposed to preservation of wetlands:

"Let Us Help You Drain Your Wet Land! Come In and Talk Over Your Drainage Problems With Us!

Some of the most productive soil in the world is wasteland in Iowa because it is not drained."

1954 Four modern trucks are pictured in a company promotional brochure,. The fleet of trucks "serves an area of 150 miles in all directions from Rockford."

1957 Natural gas replaces coal as the principal fuel for the kilns at Rockford Brick and Tile Company.

1960 Rockford Brick and Tile Company celebrates its 50th Anniversary.

1961 Rockford Brick and Tile completes installation of two new tunnel kilns at a cost of $250,000. Each kiln is 236 feet long and the first of their kind in Iowa. Sixteen beehive kilns continue to be available for use during times of peak production to assure ample tile supply.

1961 approx. Rockford Brick and Tile takes delivery of a fleet of 8 tractors (trucks) and 17 trailers. The fleet was built by international Harvester and is the first specifically designed for hauling and stringing drain tile.

1972-73 A prospective fossil buyer requests 100 pounds of fossils to evaluate the potential market value of the fossils. President Grover H. Galvin, Jr. indicates that the fossils will be sent, and the company begins investigating the washing and processing of shale for fossils. This resulted in the brick and tile grounds being closed to fossil collecting for a period of time in 1973. (It was explained to the author of this article that a major oil company was investigating the use of fossils as an advertising promotion). Nothing materialized however, and the grounds were once again opened to fossil collectors.

1973 Minutes of the Board of Directors meetings indicate that Rockford Brick and Tile has added plastic tubing to its line of products with sources from plants in Oelwein, Iowa and Findlay, Ohio.

1976 According to a special "Our Heritage" article by Floy Wyatt Michell, July 1976, Rockford Brick and Tile employed 60 persons in 1976, with eight salesmen in Iowa and Minnesota. Annual drain tile sales were close to $2 million and annual brick sales (out of state suppliers) was around $1 million. The plant was producing 38,000 tons of drain tile per year and nearly one-half million tons of clay had been dug since the plant began operating some 60 years ago.

1977 Rockford Brick and Tile is sold to Allied Construction Company and production facilities are closed. Allied continues the policy of Rockford Brick and Tile of allowing educational groups access to the grounds to collect fossils.

1989 Newspaper articles report the concern that the "fossil-laden pits" at Rockford might become a dump site. The Floyd County Board of Supervisors approved landfills for non-toxic materials at four locations, zoned for heavy industry. The former Rockford Brick and Tile clay pit is one of the sites. Conservationists, educators, geologists, and others launch a lobbying and letter-writing campaign to "save the fossil beds".

1989 The Floyd County Board of Supervisors, the Iowa Department of Natural Resources, and the Iowa Natural Heritage Foundation work together to have the grounds of the former Rockford Brick and Tile Company appraised so that a bid can be made to Allied Construction Company, current owners of the site.

1990 Rockford celebrates "Fossil Days" as a community promotion. The former Rockford Brick and Tile grounds, now owned by Allied Construction Company, continues to receive heavy use by area school groups. At least 28 classes, totaling more than 800 students visited the site last year.

1990 The REAP (Resources Enhancement and Protection Program) proposal of the Floyd County Conservation Board is funded, allowing for the purchase and development of the former Rockford Brick and Tile property. The Floyd

County Conservation Board was awarded $81,546 to purchase the 109-acre grounds and an adjoining 47-acre prairie site.

1991 The Rockford Fossil and Prairie Area is officially dedicated. Lieutenant Governor Joy Corning participates in the ribbon-cutting ceremony.

THE ROCKFORD FOSSIL AND PRAIRIE AREA

Dedicated in 1991, the Rockford Fossil and Prairie Area serves as a splendid example of what can be accomplished through the cooperative efforts of county government, state agencies, and the private sector. The Floyd County Conservation Board received the state's first Resources Enhancement and Protection (REAP) grant. Funding was provided to purchase the 109-acre former Rockford Brick and Tile property and an adjoining 47-acre prairie site, west of Rockford. Much credit should be given to Wayne Meyer, former Director of the Floyd County Conservation Board, for his efforts, energy, and vision in bringing the proposal for a fossil and prairie area to fruition.

The Rockford clay pits are known worldwide for their rich deposits of Devonian fossils, and the adjoining prairie represented one of the largest remaining native-prairie tracts in Floyd County. The 47-acre prairie area borders the 30-acre Juniper Hill Preserve, a state preserve maintained by Floyd County. Thus, acquisition of the new tract provided Floyd County with 186 contiguous acres and provided the opportunity to develop and maintain a unique natural area for biology, geology, nature study, and recreation.

Fossils are so abundant at the Rockford site that collecting is allowed even encouraged, a highly-unusual situation for a preserve. The opportunity to collect a variety of well-preserved fossils, weathered free from the rock matrix, makes the Rockford pit a popular collecting spot for school groups. Spoil piles from the clay pits contain innumerable fossils and thousands of "new" specimens are released with each rain. The opportunity to collect a variety of fossils in a short duration of time makes the area a popular tourist attraction as well. For that reason, the local chambers of commerce and civic groups lent support to Floyd County to develop the area as a preserve and recreational area. The town of Rockford celebrates its heritage in appropriate fashion with an annual summer festival known as "Fossil Days" (Stone, 1990).

The Juniper Hill portion of the preserve is home to an unusual species of creeping juniper. Known as *Juniper horizontalis,* the low-growing shrub is on the endangered species list. Juniper Hill is believed to be the only place in the continental United States where this rare species grows (Jacobs, 1994).

The juniper occurs in 2 1/2 acres of the preserve and appears to grow only on soils developed on the Cerro Gordo Member of the Lime Creek Formation. Distribution of the creeping juniper may be related to Late Wisconsinan glacial events. Although the Juniper Hill locality is in the area of the state's Pre-Illinoian glacial deposits, it is a mere 10 to 15 miles east of the margin on the Des Moines Lobe.

Future development of the Rockford Fossil and Prairie Area depends on funding. Wayne Meyer, former Director of the Floyd County Conservation Board, envisioned a restored wetland on adjacent land to the north, eight to ten miles of hiking trails connecting the site to the city park at the west edge of Rockford, and restoration of one of the beehive kilns at the former plant site. Craig Ritland, landscape architect, has prepared a master plan for the area (pp. 12-13), and Kevin Hicok produced a video on "The Rockford Fossil and Prairie Area" as part of an Eagle Scout Project.

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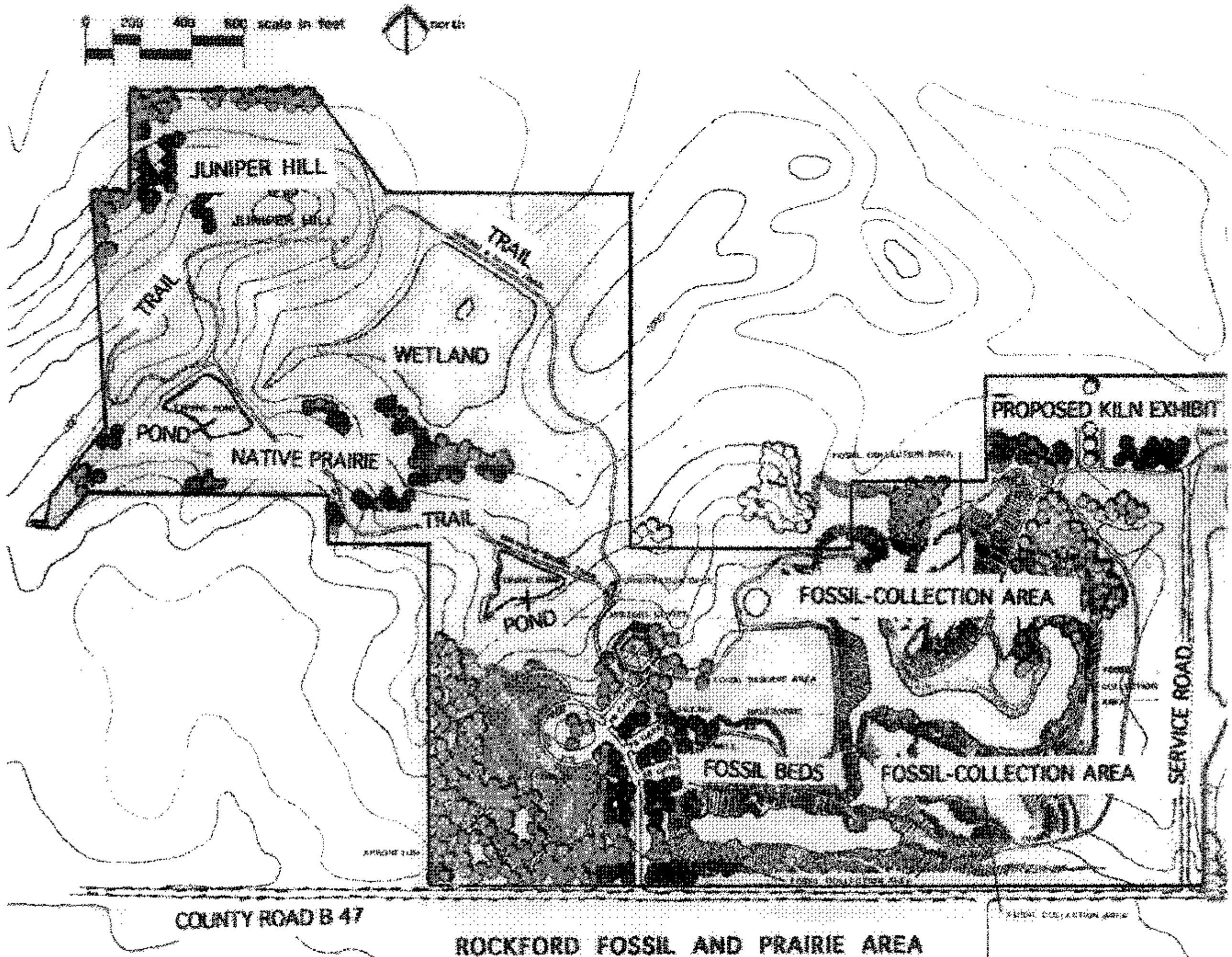
MASTER PLAN FOR ROCKFORD FOSSIL AND PRAIRIE AREA

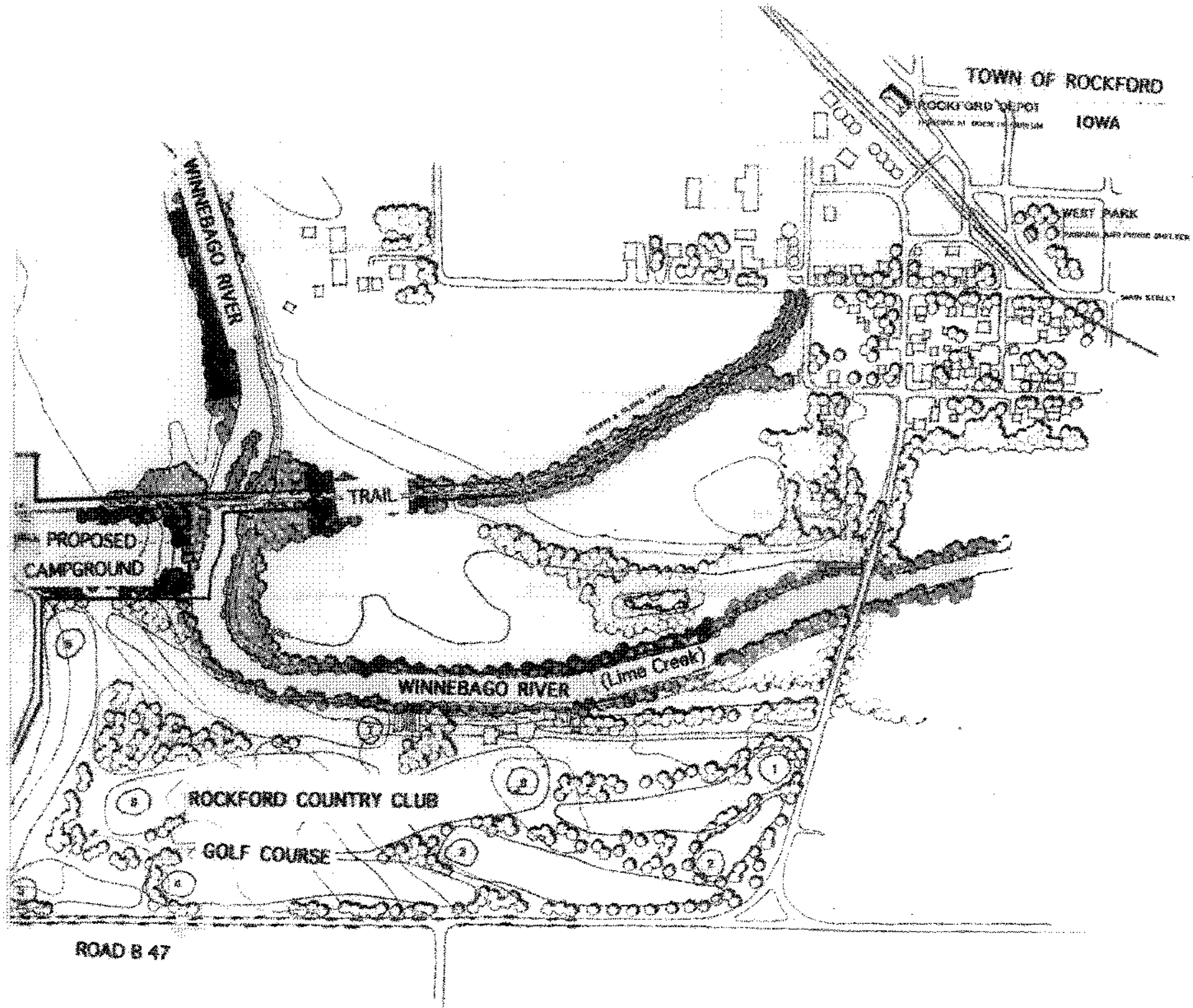
Craig Ritland, Landscape Architect



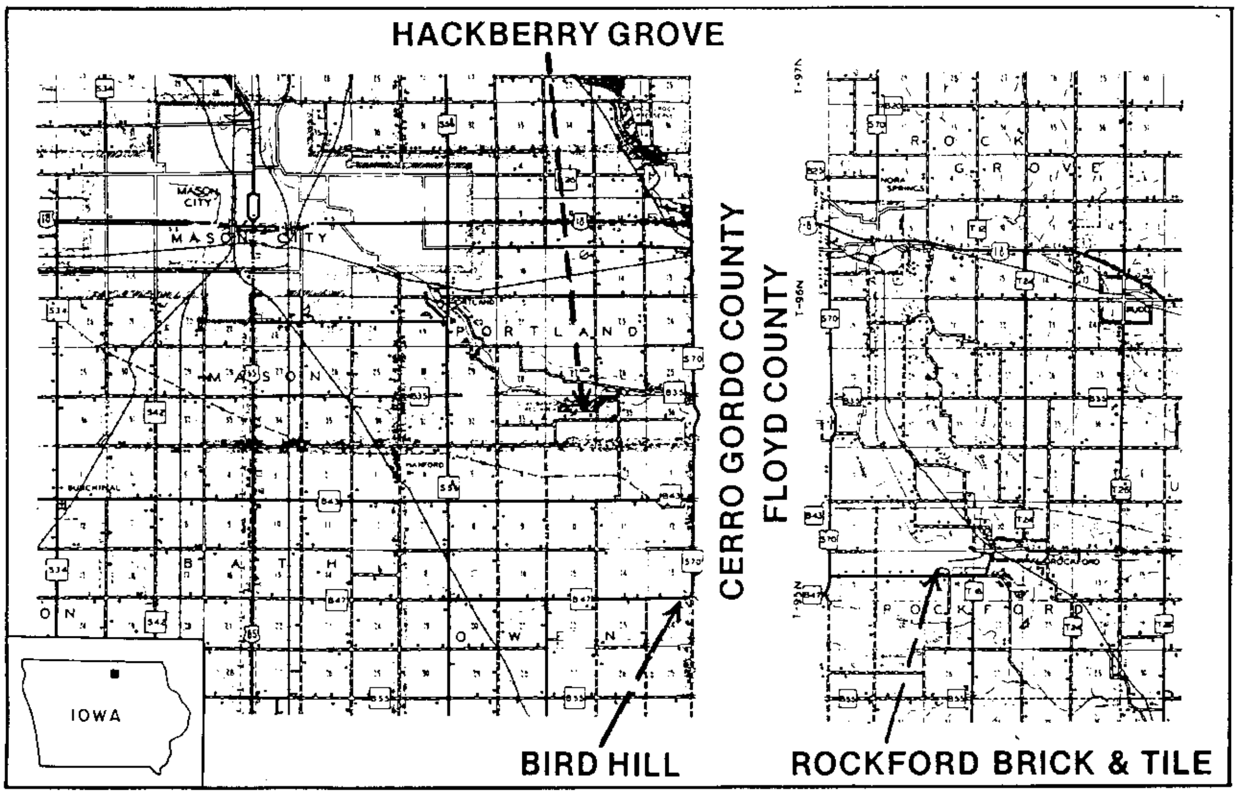
ROCKFORD FOSSIL AND PRAIRIE AREA

FLOYD COUNTY CONSERVATION BOARD

The Master Plan for the Rockford Fossil and Prairie Area envisions a visitor center and kiln exhibit



on the grounds and a hiking trail connecting the grounds to the nearby town of Rockford.



Location map of the former Rockford Brick and Tile grounds (now the Floyd County Fossil and Prairie Area, Bird Hill, and Hackberry Grove localities . (From Anderson and Furnish, 1987, p. 89)

THE LIME CREEK FORMATION IN THE ROCKFORD AREA: A GEOLOGICAL PERSPECTIVE

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INTRODUCTION

Anderson and Furnish (1987) prepared a description of the Lime Creek Formation of north-central Iowa for the Geological Society of America Centennial Field Guide. What follows is an updated and edited version of that discussion.

There are three well-known exposures of the Lime Creek Formation in the area between Charles City and Mason City in northern Iowa. The best known of the three is the former Rockford Brick and Tile quarry (now the Floyd County Fossil and Prairie Area). The Juniper Hill State Preserve is included in the Fossil and Prairie Area. Bird Hill, also a state preserve, is located a few miles farther west on an east-west county right-of-way. The stratigraphic section known as "Hackberry Grove", now the Claybanks Forest Preserve, is located along the south bank of the Winnebago River. It is administered by the Cerro Gordo County Conservation Board. The three localities are shown on a location map below.

SIGNIFICANCE

During a cold and snowy Iowa winter, it might be difficult to envision the ancient subtropical setting associated with the Lime Creek Formation of northern Iowa. When the snows melt in the spring, however, the evidence is obvious and abundant. Thousands of well-preserved invertebrate fossils weather free from the soft shales and limestones of the local bedrock in western Floyd and eastern Cerro Gordo counties. Dozens of choice specimens can be collected in a few minutes, and the fossils of the Lime Creek Formation are well known to both professional paleontologists and amateur fossil collectors. During field investigations for Iowa's first state survey, Edward Hungerford and J. D. Whitney collected spiriferid brachiopods from the fossiliferous Lime Creek beds, west of Rockford. These species, new to science, were named and illustrated by the illustrious geologist-paleontologist James Hall in 1858 (Hall and Whitney, 1858).

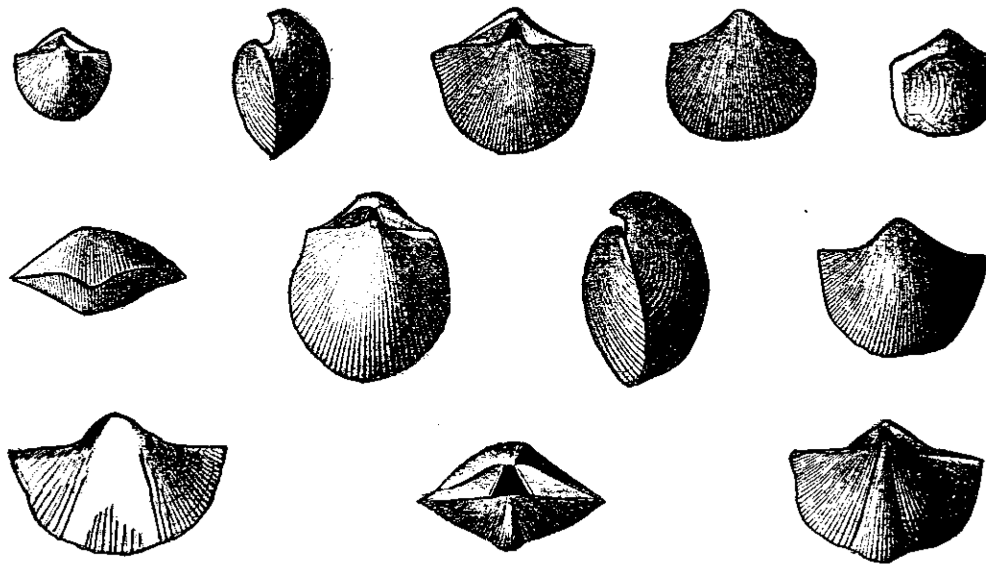
Theodossia hungerfordi and *Cyrtospirifer whitneyi* (illustrated later in this section) are two of the more common brachiopods in the Lime Creek Formation in the Rockford area, so you stand an excellent chance of adding them to your collection. Although the names of Hungerford and Whitney were immortalized by James Hall, Hungerford's name may not be too well known outside of paleontological circles. Whitney's name, however, remains prominent. The highest mountain in California (and the highest in the United States outside of Alaska) was named in honor of Josiah D. Whitney, first State Geologist of California (McPhee, 1993).

Fenton and Fenton (1958) opened "The Fossil Book" with a description of the fossils of Rockford, Iowa. The reconstruction shown later in this section is based on that information.

SITE INFORMATION

An updated lithostratigraphic section of the Lime Creek Formation is presented elsewhere in the guidebook by Jed Day of Illinois State University. Generalized sections of the Lime Creek Formation at the quarry of the former Rockford Brick and Tile Company and at the Bird Hill locality are shown below for reference purposes.

The Lime Creek Formation is divided into three members, in ascending order: Juniper Hill Member, Cerro Gordo Member, and Owen Member.



"*Spirifer hungerfordi*" (upper two rows) and "*Spirifer whitneyi*" (lower row) are shown as illustrated in Geological Survey of Iowa, Plate 4, Hall and Whitney (1858). Actual size of typical specimens, 15-35 mm. in width.

The Cerro Gordo Member is the most fossiliferous of the three, and a variety of fossils can be collected from these beds on the field trip today.

Belanski (1931) divided the Hackberry Formation (Owen and Cerro Gordo members of current usage) into 45 zonules or beds, based on fossil content and rock types. William Furnish verified Belanski's stratigraphic divisions, to the inch, when he completed a set of trenches at the Rockford Brick and Tile and Bird Hill localities in 1935 and 1936.

The section of the Cerro Gordo Member at Hackberry Grove is complete, but it may need to be exposed by digging as it is generally covered with weathered debris. The lower portion of the Cerro Gordo Member can be studied in detail at the Rockford Fossil and Prairie site. The upper Juniper Hill shales and lower Cerro Gordo beds were used in the manufacture of brick and tile for many years. These beds were known as the " blue clay" deposits by early workers. The contact of the Juniper Hill Shale with the underlying Shell Rock Formation can be seen along the north bank of the Winnebago River, west of Rockford and at the Hackberry Grove site when the river stage is low.

Clement L. Webster, a school teacher at Charles City, published several articles on the rocks of the Rockford area, referring to the strata as "the Hackberry beds" (Webster, 1889). The name "Hackberry" was also utilized in publications by the Fentons (Fenton, 1919; Fenton and Fenton, 1924). However, the Iowa Geological Survey, since the 1890s, had consistently favored use of the name "Lime Creek Formation" for beds In the Rockford area. In 1944, M. A. Stainbrook proposed that the name "Hackberry" be discontinued in favor of "Lime Creek Formation", and this convention has been followed since.

PALEONTOLOGY

Fenton (1919) published a faunal list for the "Hackberry Stage" (Owen and Cerro Gordo members of today's usage). This faunal list provides some indication of the diversity of the "Hackberry Fauna", although taxonomic concepts and practices have changed considerably since Fenton's time. Fenton recorded 83 taxa from the Owen Member and 143 taxa from the Cerro Gordo Member. The faunal list included species of brachiopods, bryozoans, cephalopods, corals, echinoids, gastropods, pelecypods, and stromatoporoids.

Fenton and Fenton (1924) illustrated and described the megafauna of the Cerro Gordo and Owen members. Although their taxonomy needs revision, their study represented a thorough and systematic study of the "Hackberry Fauna" for the time. The Fentons attempted to deal with all components of the megafauna; subsequent studies have been less comprehensive.

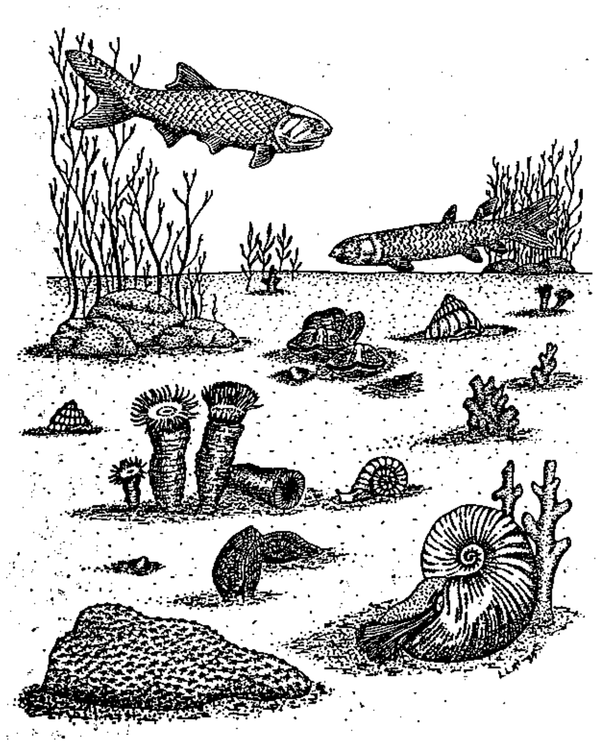
Brachiopod faunas, along with the ammonoid *Manticoceras*, document the Late Devonian (Frasnian) age of the Cerro Gordo Member. Anderson (1966) described conodonts from the Lime Creek Formation, providing additional evidence for the Late Devonian (Frasnian) age for these beds.

Day (1987) published a revised taxonomy for two genera of gastropods from the Lime Creek Formation, and in 1989, he proposed five zones for the brachiopod succession found in the type Lime Creek Formation. In addition, Day (1995) has established correlations between the Lime Creek Formation of northern Iowa and the Amana Beds of eastern Iowa. Elsewhere in this guidebook, Day provides an updated discussion of the stratigraphy and paleontology of the Lime Creek Formation.

J. E. Sorauf, State University of New York at Binghamton, is preparing a monograph on "The Upper Devonian, Frasnian, corals of Iowa" for the Bulletin of American Paleontology. That publication, available in late 1995 or early 1996, will provide new and revised taxonomy for corals from the Shell Rock and Lime Creek formations of Iowa (Sorauf, 1995).

Carl W. Stock, The University of Alabama, reports that he has not found a stromatoporoid at the Rockford Brick and Tile site in several visits since 1968. He speculates that conditions in the Late Devonian sea were too muddy for stromatoporoids at the time the beds of the Cerro Gordo Member were laid down in the Rockford area.

Stock (1984a) provided information on stromatoporoids from the Cerro Gordo and Owen members for the Tri-State Geological Field Conference Guidebook. He reported two species of stromatoporoids from the Cerro Gordo Member in eastern Cerro Gordo and eastern Franklin counties. These stroms generally grew by encrusting

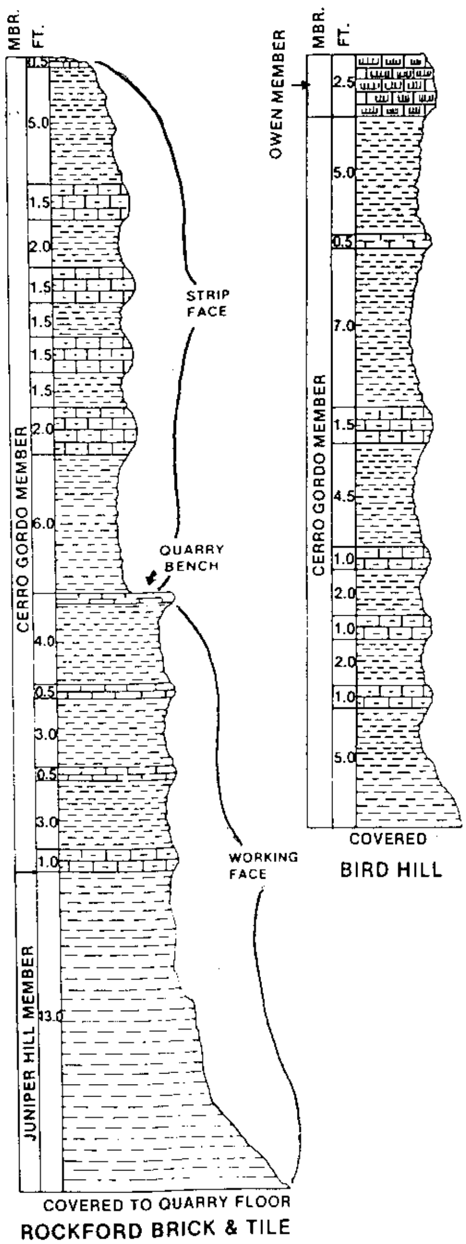


Reconstruction of the Devonian seafloor during deposition of the Cerro Gordo Member of the Lime Creek Formation. Drawing by Lori McNamee from the Guidebook for the 48th Annual Tri-State Geological Field Conference. Drawing is based on information in ***The Fossil Book*** by C. A. Fenton and M. A. Fenton, 1958, Doubleday and Company, Inc., Garden City, N.Y.,p. 1.

other fossils such as brachiopods and gastropods. Stock noted eight species of stromatoporoids from the Owen Member and observed that occurrences reached biostromal abundances in places.

The base of the Owen is usually marked by a bed of stroms, the "*Idiostroma* Zone" of Fenton (1919). However, Stock (1984a) assigned these forms to the genus *Amphipora*. The *Amphipora* horizon is exposed at the Bird Hill locality.

Megafossils from the Cerro Gordo Member commonly are encrusted with other fossils (epibionts). Epibionts are particularly common on brachiopods, and they also are found on horn corals. The occurrence and arrangement of the epibionts suggests attachment and subsequent

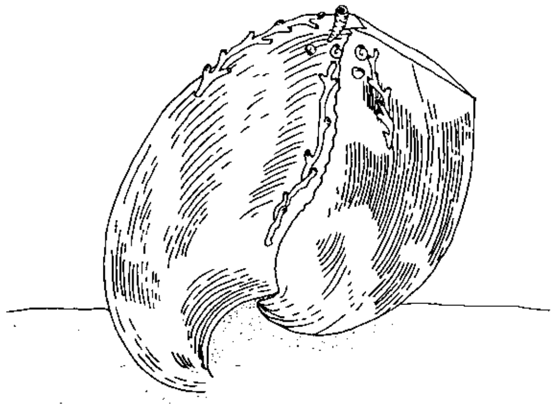


Lithostratigraphic sections of the Lime Creek Formation at the Rockford Brick and Tile and Bird Hill localities. (From Anderson and Furnish, 1987, p. 90)

growth on either living or dead organisms. Common epibionts include calcareous worm tubes,(*Spirorbis* sp.), conical shells (*Cornulites* sp.), auloporid tabulate corals, branching bryozoans (*Hederella* sp.), juvenile horn corals, and inarticulate brachiopods. In addition, some brachiopods are penetrated by circular borings, possibly caused by polychaete worms, and etched with dendritic grooves and channels of the type attributed to clionid sponges. Favorable attachment sites for small suspension feeders were probably limited because of widespread muddy conditions on the sea floor during deposition on the Cerro Gordo beds. In all likelihood, brachiopod shells and other larger invertebrates provided some of the few locations that were relatively free of mud, and these were the areas where epibionts attached, grew, and survived (Anderson and Megivern, 1982). Representative epibionts are illustrated below.

A diverse assortment of microfossils can be recovered from residues of the Juniper Hill and Cerro Gordo beds from localities in the Rockford area (Anderson, 1976; Wilson and McNamee, 1984). The following fossils can be found from screened residues: brachiopods, bryozoans, charophytes, crinoid stems, conodonts, foraminifera, gastropods, megaspores, ostracods, scolecodonts, sponge spicules, and tentaculitid shells. D. Louis Finsand, Professor of Teaching at Price Laboratory School, Cedar Falls, has shared the excitement associated with microfossil activities with countless teachers at National Science Teachers' workshops through the years. He has provided teachers with class-size quantities of partially-washed residues from the Lime Creek Formation so that elementary and secondary teachers and students can experience the thrill of discovering and recovering a variety of well-preserved microscopic fossils.

Additional references dealing with the Lime Creek fauna include: Baker and others (1986), Conklin and others (1972), Cushman and Stainbrook (1943), Gibson (1952), Johnson (1974), Kier (1968), Newport and Urban (1974), Peck and Morales (1966), Stock (1984b), Strimple and Levorson (1971), and Tuftin (1984).



Epibionts are common on brachiopods from the Lime Creek Formation in western Floyd and eastern Cerro Gordo counties. Idealized brachiopod shown with encrusting epibionts: auloporid corals, branching bryozoans, calcareous worm tubes, and conical shells. (From Anderson and Megivern, 1982)

DEPOSITIONAL SETTING

Witzke (1987) provided a detailed interpretation of the environment of deposition for the Lime Creek Formation and provided comparisons with laterally-adjacent stratigraphic units. According to Witzke, the Lime Creek Formation in the Rockford area represents a shallowing-upward sequence of subtidal environments with the Juniper Hill Member reflecting an oxygenated to marginally-oxygenated setting. The Cerro Gordo Member was deposited in an oxygenated environment, below normal wave base. The Owen Member formed under shallower deposition, partly under wave-washed conditions.

Prior to the Late Frasnian (Lime Creek) transgression across the central midcontinent, karst features developed over a wide area. Caverns, sinkholes, and other solution features formed on Silurian and Middle Devonian limestones and dolomites. Stratigraphic leaks of the Lime Creek Formation and its equivalents (Independence Shale) filled many karst features (Bunker and others, 1988).

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THE BRACHIOPOD FAUNA OF THE UPPER DEVONIAN (LATE FRASNIAN) LIME CREEK FORMATION OF NORTH-CENTRAL IOWA, AND RELATED DEPOSITS IN EASTERN IOWA

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INTRODUCTION

The Lime Creek Formation of Iowa features one of the best studied marine invertebrate faunas of Early Upper Devonian (late Frasnian) age in North America. Because of the superb preservation and spectacular abundance of fossils readily collected in easily accessible quarry exposures and outcrops, fossils from Lime Creek of northern Iowa have been collected and studied by generations of professional and amateur paleontologists for nearly 150 years. Although numerous species (nearly two hundred) of marine macro-invertebrates and microfossils have been described and illustrated in dozens of scientific articles and textbooks dating to the 1850's, much of the Lime Creek megafauna is in need of modern taxonomic revision and redescription. Many common Lime Creek fossils (especially bivalves, gastropods, stromatoporoids, and bryozoans) have never been described, including a number of undescribed species of brachiopods. Brachiopods are an extremely abundant and dominant part of the Lime Creek macroinvertebrate fauna seen in outcrops and other exposures in western Floyd, and eastern Cerro Gordo counties in north-central Iowa.

My recent studies of Late Frasnian deposits in the Iowa Basin (Figs. 1 and 2) have been concerned with the brachiopod and conodont biostratigraphy of the Lime Creek Formation. Over the last decade I have assembled a great deal of data on the composition and stratigraphic distribution of most brachiopod species in the Lime Creek and other related units in Iowa, which is available in Day (1989, in press).

The Iowa Basin late Frasnian age brachiopod sequence documented in those studies provides one the best studied biological records in North America for the time interval preceeding the global mass extinction that occurred at the Frasnian-Famennian boundary. Virtually all major groups of brachiopods, corals, molluscs, bryozoans, and echinoderms (genera, families, certain orders) represented in the Lime Creek and other late Frasnian faunas worldwide became extinct during the latest part of the Frasnian. Of the approximately 71 brachiopod species seen in the late Frasnian age deposits in Iowa, only five are known to survive into the early Famennian in North America.

In the remainder of this study, I summarize the general aspects of the stratigraphy the spectacular late Frasnian age brachiopod fauna developed in the Lime Creek Formation of north-central Iowa, and facies of the Lime Creek (Amana Beds and Independence Shale) in eastern Iowa.

DEPOSITIONAL SETTING OF THE LIME CREEK FORMATION

A regional cross section of the Middle and Upper Devonian strata in central North America, showing the position and distribution of the Lime Creek Formation is illustrated in Figure 1. Current stratigraphic, biostratigraphic, and sea level frameworks for Middle-Upper Devonian rocks of the Iowa Basin are summarized in Figure 2. The regional depositional history and setting of the Lime Creek Formation of northern Iowa and its equivalents in eastern Iowa has been outlined in Witzke (1987) and Day (1990, in press). A modified version of Witzke's (1987) depositional model for the Lime Creek-Sweetland Creek seaway in the Iowa and Illinois basins is shown in Figure 3.

In its type area, the Lime Creek forms a single

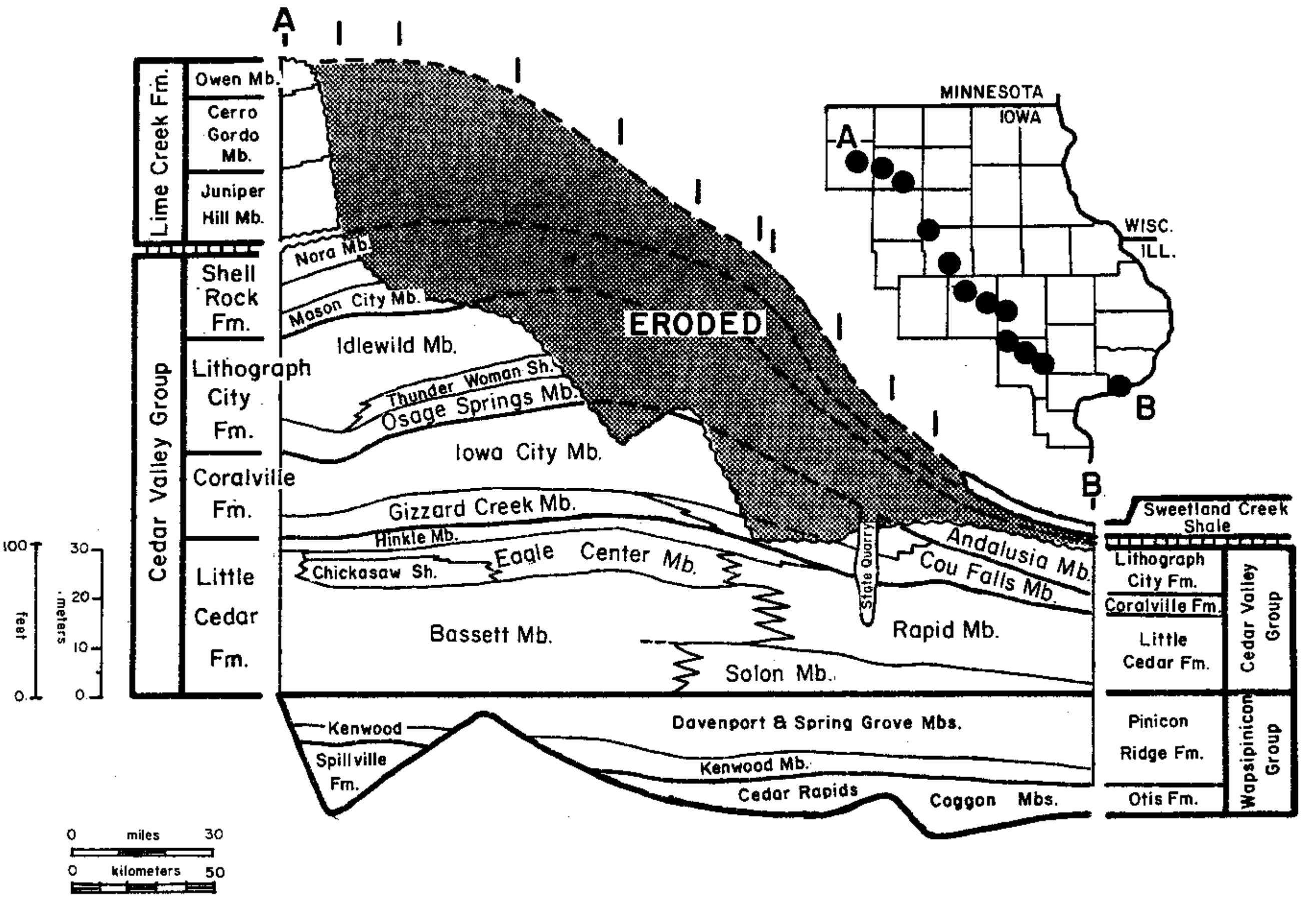


Figure 1. Cross section of Middle and Upper Devonian (Eifelian-Famennian) strata of the Iowa and Illinois basins and major tectonic features in the area of the U.S. midcontinent Devonian carbonate platform. After figure 4 of Witzke and others (1989)

large-scale shallowing upwards succession of shales and carbonate rocks that accumulated during a single large scale transgressive-regressive cycle during the latter part of the Frasnian Stage of the Upper Devonian (Fig. 2). The late Frasnian sea level rise (Fig. 2) that initiated Lime Creek-Sweetland Creek Shale deposition in the Iowa Basin is designated as Iowa Devonian Transgressive-Regressive (T-R) cycle 7 of Witzke and others (1989), which corresponds to Devonian eustatic T-R cycle IId of Johnson and others (1985) and Johnson and Klapper (1992) as shown in the top right column of Figure 2.

Strata of the Lime Creek Formation were deposited in mid-outer shelf environments near the margin of a immense carbonate platform (Fig. 3). During the regressive stage of Lime Creek deposition, shallow water inner-platform and platform margin facies of the Owen Member of the Lime Creek prograded from the west and north to the current vicinity of the type area of the Lime Creek in northern Iowa. Seaward of the platform margin, deeper-water facies of the Lime Creek accumulated in ramp/slope and anoxic basin settings that had developed across what is now eastern Iowa and the Illinois Basin (Fig. 3).

These deeper water facies include: the Amana Beds of Iowa County (Fig. 4, localities 1 and 2; Fig. 5); the Independence Shale of Buchanan County (Fig. 4, locality 4); the North Liberty Beds of

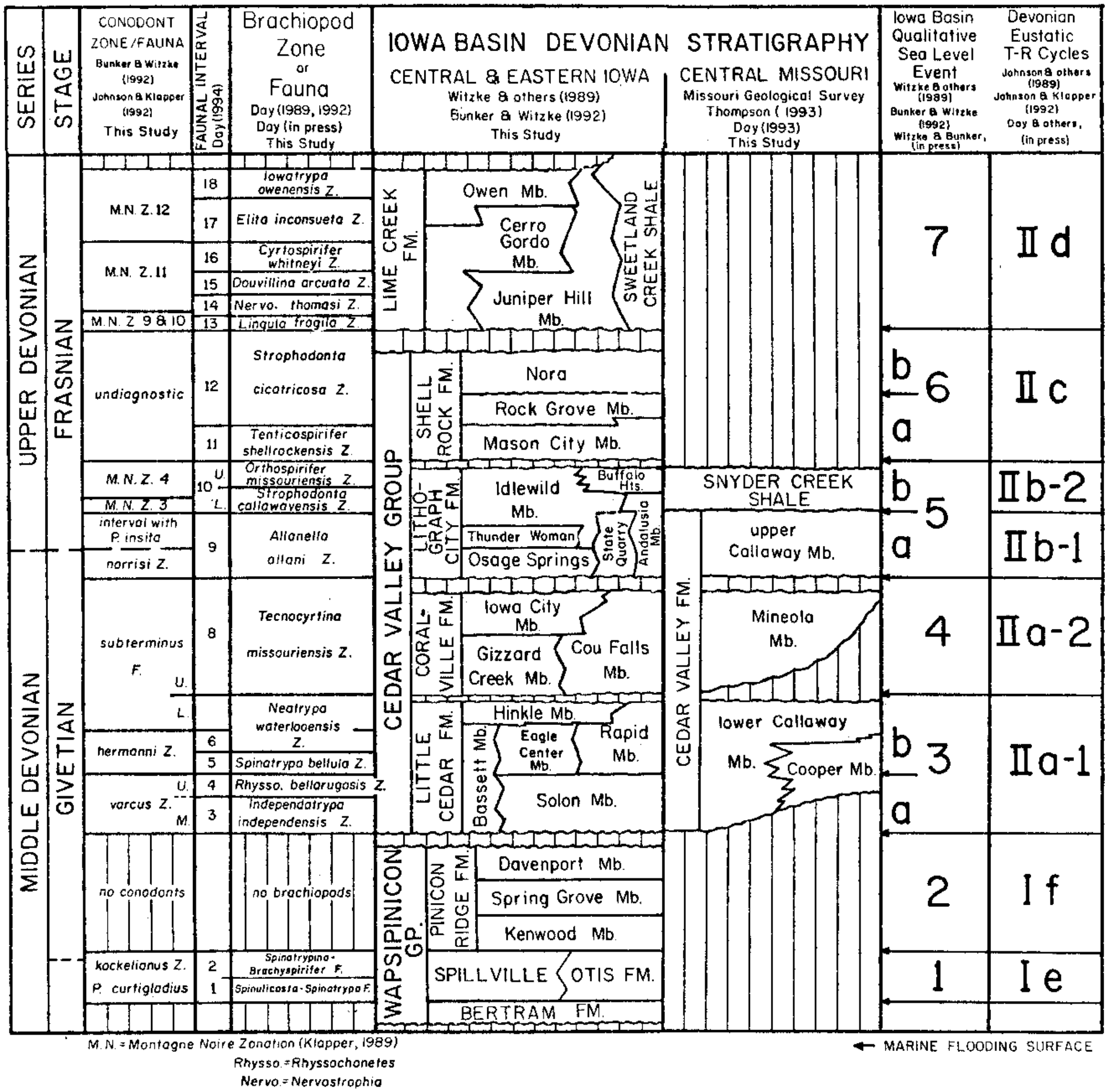


Figure 2. Stratigraphic and biostratigraphic framework for the Middle-Upper Devonian (Eifelian-Frasnian) strata in the Iowa Basin, showing relationships of the Iowa Devonian sea level framework (Witzke and others, 1989; Bunker and Witzke, 1992; Witzke and Bunker, in press) and Devonian eustatic Transgressive-Regressive (T.R.) cycles (Johnson and others, 1985; Johnson and Klapper, 1992; Day and others, 1994, in press). A new Iowa Devonian lithostratigraphic unit was named the Buffalo Heights Member of the Lithograph City Formation in Day (in press-b). New Devonian brachiopod zones defined since studies by Day (1989, 1992) include the *Orthospirifer missouriensis* Zone (Day, in press-b) and *Lingula fragila* Zones (Day, in press-a). Modified from figure 3 of Day (in press-b).

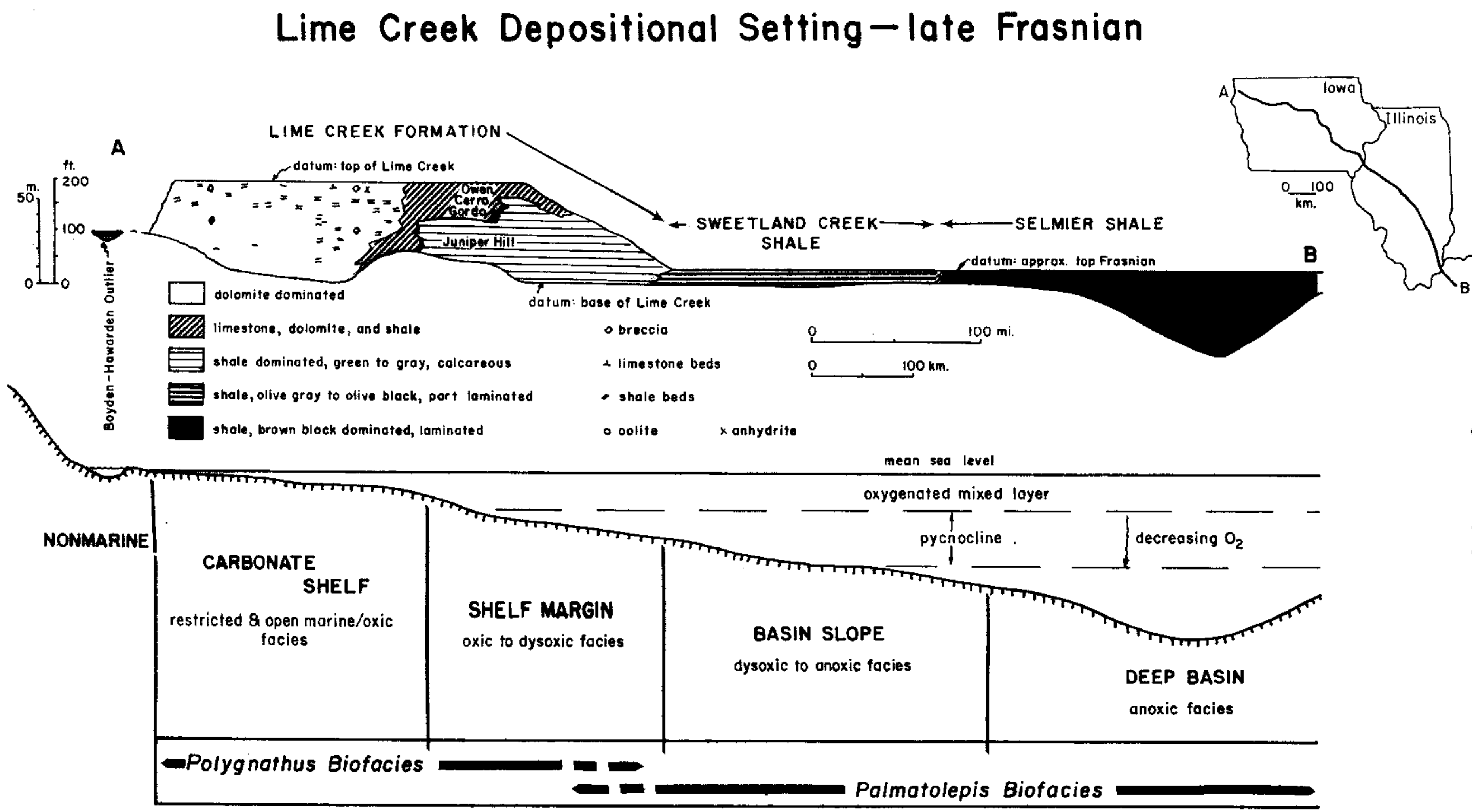


Figure 3. Cross section of late Frasnian age rocks in the central U.S. midcontinent and interpreted bathymetric profile and depositional setting from north-central Iowa into the Illinois Basin. Also shown are distributions of conodont faunas of the shallow-water Frasnian *Polygnathus* of Klapper and Lane (1985, 1989) and the offshore *Palmatolepis* biofacies (Modified from fig. 5 of Witzke, 1987; after fig. 4 of Day, 1990).

Johnson County (Fig. 4, locality 5); and the Sweetland Creek Shale of Muscatine County (Fig. 4, locality 6). Of these, the former two shale-dominated units contain calcareous shelly fossils which colonized and occupied deeper-water sea floor habitats in the Lime Creek-Sweetland Creek seaway. The latter two units accumulated in even deeper water, where bottom conditions (either anoxia or temperature) excluded stenotypic invertebrates such as articulate brachiopods.

PREVIOUS FAUNAL STUDIES OF THE LIME CREEK FORMATION

Fossils, including brachiopods, from the Lime Creek Formation of Iowa were first described by Hall (1858). Most of the Lime Creek brachiopod fauna was subsequently described in Hall and Whitfield (1878), Calvin (1876, 1878, 1883, 1891, 1892), Webster (1889, 1905, 1908, 1909, 1921), Fenton (1918, 1931), Belanski (1928a, 1928b), Fenton and Fenton (1924, 1930, 1932, 1935), Thomas (1922), Thomas and Stainbrook (1921), Stainbrook (1945, 1946a). A variety of late Frasnian brachiopods from Iowa have been redescribed, illustrated, or discussed in more current paleontological investigations, including: Copper (1973, 1978), Cooper and Dutro (1982), Day (1987b, 1989, 1995, in press), and Copper and Chen (1995).

Day's (1989, in press) studies of the Iowa late Frasnian age brachiopod faunas feature current identifications of all previously described species known from the Lime Creek and related strata in eastern Iowa. Current generic names for all described and undescribed brachiopods known from late Frasnian age deposits in Iowa are listed in Table 1. The current biostratigraphic zonation of the Lime Creek Formation is shown in Figures 2, 5 and 6. The Lime Creek brachiopod zonation was developed in two recent studies by Day (1989, in press). The brachiopod zonation of the Lime Creek now consists of six intervals, which are in ascending order, the *Lingula fragila, Nervostrophia thomasi, Douvillina arcuata Cyrtospirifer whitneyi, Elita inconsueta*, and *Iowatrypa owenensis* zones (Figs. 2, 5, 6).

Additional data on Lime Creek brachiopod

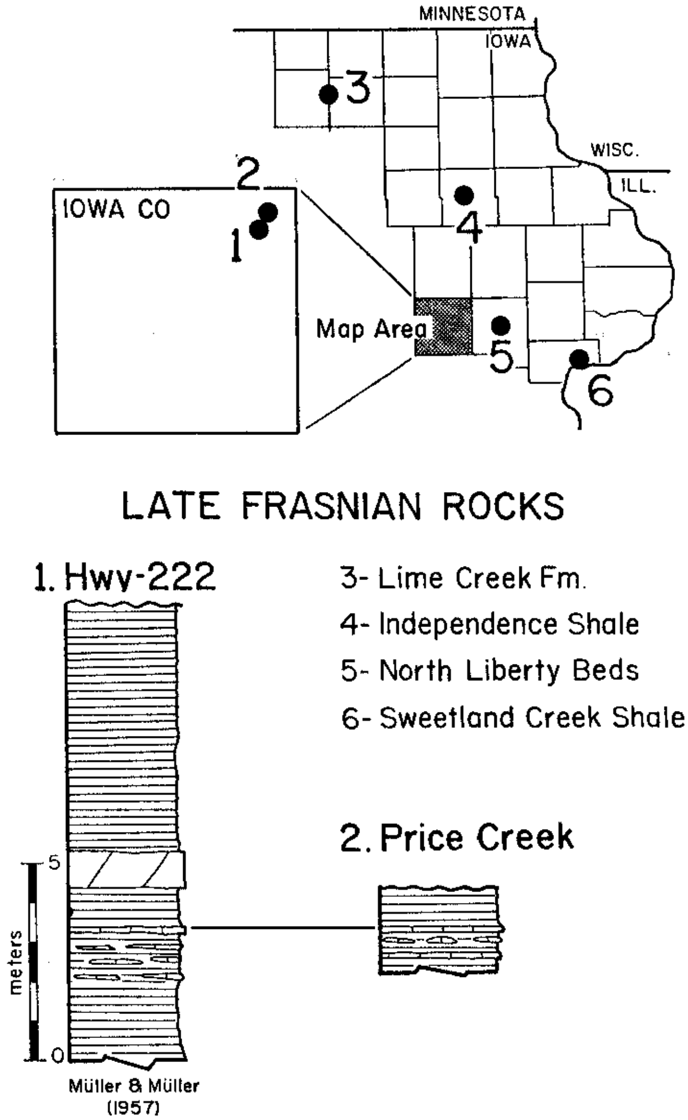


Figure 4. Map showing locations and names applied to late Frasnian age rocks in central and eastern Iowa. Below, stratigraphic sections illustrate proposed correlations of the Amana Beds at its type section (locality 1) and new exposures discovered on Price Creek in 1993 (locality 2). Locality Key: 2.—Lime Creek Formation in western Floyd and Cerro Gordo counties (see map in Fig. 6); 4.—Independence Shale (type area) near Independence in Buchannon County; 5.—North Liberty Beds at its type section and well core in northern Johnson County; and 6.—Sweetland Creek Shale in Muscatine County.

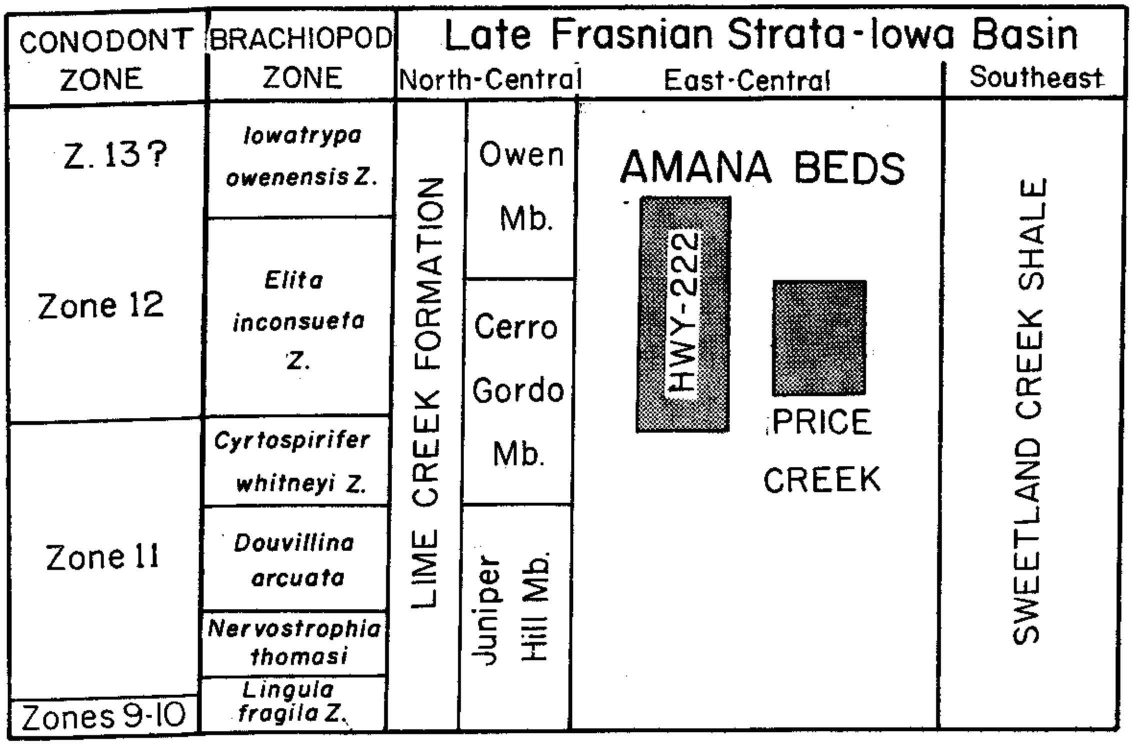


Figure 5. From right to left, conodont and brachiopod zonations and proposed correlations of the of the Lime Creek Formation, Amana Beds, and Sweetland Creek Shale. See Figure 4 for locations of units. Brachiopod zonation for the Lime Creek Formation after Day (1989a, in press). Conodont zones after Montagne Noire Frasnian zonation of Klapper (1989).

occurrences in the Cerro Gordo and lower part of the Owen Member at the Hackberry Grove locality (Fig. 6, locality 4; Fig. 8) was outlined in an unpublished study by Leslie Jones in 1988 (University of Northern Iowa). Selected brachiopod ranges (documented in Jones' study) in the Cerro Gordo and Owen members in the Lime Creek section at Hackberry Grove is summarized in Figure 8.

Other studies featuring descriptions or discussions of other groups of common Lime Creek fossils include: foraminifers in Cushman and Stainbrook (1943), Metzger (1989), and Day (1990); conodonts in Anderson (1966), Metzger (1989), Woodruff (1990), Day (1990), Klapper (1990), and Klapper and Foster (1993); ammonoids by Miller (1936), Baker and others (1986) and Day (1990); and corals by Webster (1889, 1905), Stainbrook (1946b), Sorauf (1988), and McLean and Sorauf (1989).

STRATIGRAPHY OF THE LIME CREEK FORMATION

The stratigraphy of the Lime Creek at major reference sections in its type area, including the Rockford Quarry, is shown in Figures 6 and 8. In northern Iowa (Fig. 4, locality 3; Figs. 6 and 8), the Lime Creek Formation ranges in thickness from 20-40 meters in thickness, and is divided into, in ascending order, the Juniper Hill, Cerro Gordo, and Owen members (Figs. 2, 4, and 5). The Lime Creek is substantially thicker in the subsurface to the south and west in central and western Iowa (Fig. 3) and western Nebraska (Witzke, 1987; Metzger, 1989). As mentioned above, other deposits considered as facies or informal members of

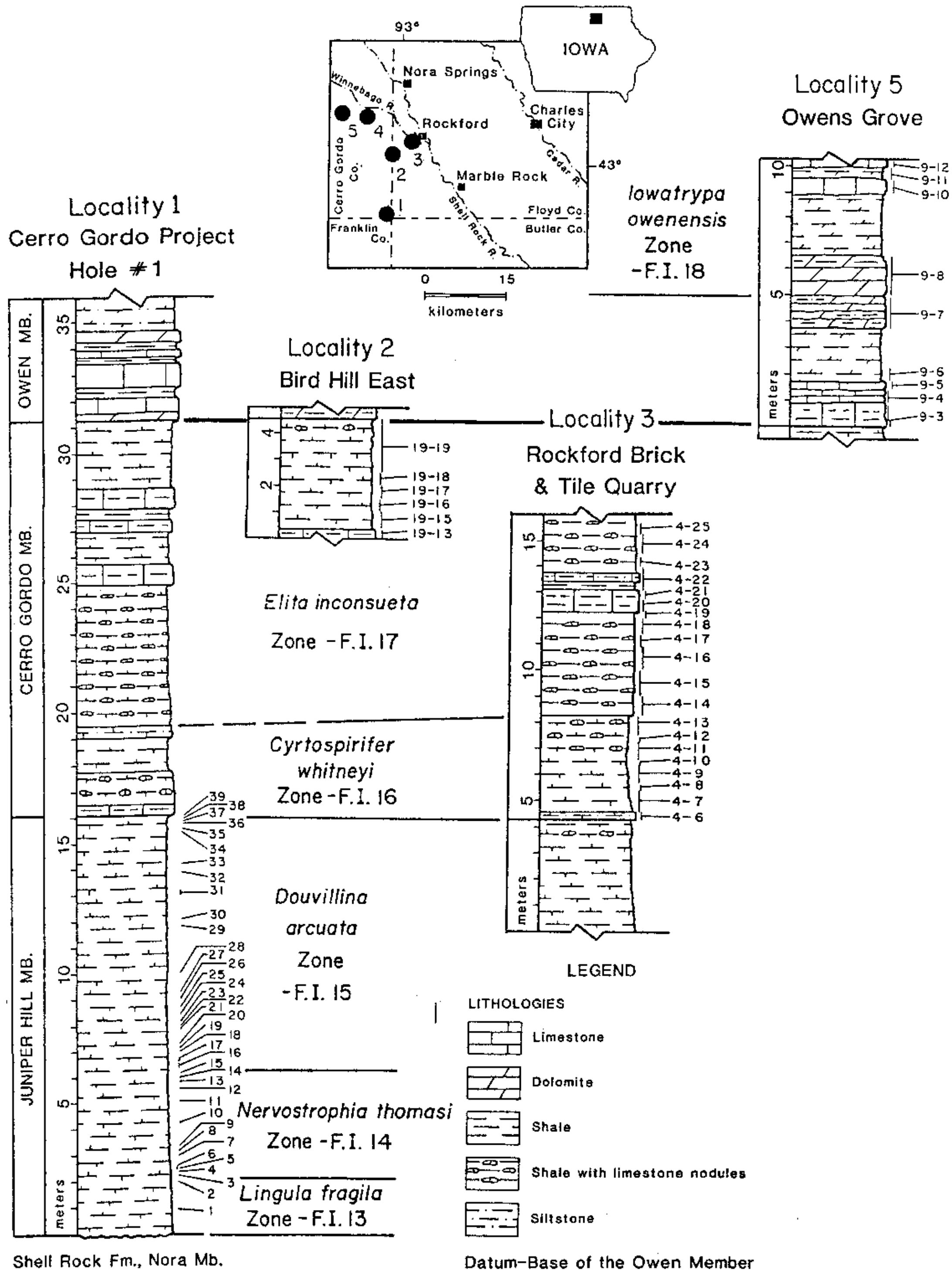


Figure 6. Map at top shows locations of important reference and type sections of various members of the Lime Creek Formation in north-central Iowa. Measured sections showing the Lime Creek stratigraphy and positions of brachiopod sample intervals at section localities 1, 2, 3, and 5 are shown, as well as the positions of brachiopod zonal boundaries defined by Day (1989a, in press).

the Lime Creek include, the Amana Beds, Independence Shale, the North Liberty Beds, and the Sweetland Creek Shale.

Juniper Hill Member

The Juniper Hill ranges from 9-16 meters in thickness, and is thickest (16.1 m) in the subsurface in the Cerro Gordo Project Hole # 1 in southeastern Cerro Gordo County (Fig. 6, locality 1). The only known complete exposure of the Juniper Hill occurs in a series of outcrops on the south bank of the Winnebago River at Hackberry Grove (Figs. 6 and 8, locality 4; =Cerro Gordo County Clay Banks Natural area). The upper third (4.3 m) of the member is seen in exposures in the pits at the Rockford Quarry locality (Fig. 6, locality 3). At the Hackberry Grove locality in Cerro Gordo County (Figs. 6 and 8, locality 4) the basal 10 cm of the Juniper Hill consists of a condensed pyritic and phosphatic (fish plates and conodonts) lag deposit, with the remainder of the member comprised of grey calcareous shales and mudstones.

Calcareous shelly fossils are rarely, if ever, found in surface exposures of the Juniper Hill Member at the Rockford Quarry and Hackberry Grove (Figs. 6 and 8, localities 3 and 4). A sparse fauna described by Webster (1908) from surface exposures of the Juniper Hill Member at the Rockford Quarry (Fig. 6, locality 3) included lingulid brachiopods (*Lingula fragila*) and carbonized vascular plant fossils. Hexactinellid sponges were later described by Thomas (1922). A sparse brachiopod fauna recovered in the 1920's from the Juniper Hill at the Rockford Quarry is listed and discussed by Belanski (Belanski Register, University of Iowa Repository) and Day (1987b, 1989a).

Most of the subsurface Juniper Hill in southeastern Cerro Gordo County yields a moderately diverse brachiopod fauna (Table 1) (Fig. 6, locality 1, sample intervals 1-39; Fig. 7, Faunal Intervals 13-15). The subsurface Juniper Hill fauna includes 21 species of articulate and lingulid brachiopods (Table 1). Most species of the Juniper Hill brachiopod fauna first appear in the intervals of the *Nervostrophia thomasi* and *Douvillina arcuata* Zones of Day (1989; see Figs. 2, 5, 6, and 7; Fig. 7, Faunal Intervals 14 and 15), and range upward and occur in abundance in the fauna of the Cerro Gordo Member.

Cerro Gordo Member

The Cerro Gordo Member ranges from 9-15 meters in thickness at surface exposures and in the subsurface in north-central Iowa (Figs. 2, 5, 6, and 8). The Cerro Gordo consists of extremely fossiliferous calcareous shales, nodular shaley limestones, and bedded argillaceous limestones. The only complete surface exposure occurs at its type section (Hackberry Grove, Fig. 6 locality 4, Fig. 8). The lower half to two thirds of the member are exposed in the Rockford quarry, and the upper half of the member is exposed in the vicinity of Bird Hill (Fig. 6). The type section of the Cerro Gordo Member is located at what is now called the Clay Banks Natural Area, maintained by Cerro Gordo County as a nature preserve (Fig. 6, map locality 4; Fig. 8).

The Cerro Gordo Member is incredibly fossiliferous, and features at least 38 species of brachiopods, most of which can be easily collected at the Rockford Quarry and other surface exposures in Floyd and Cerro Gordo counties (Figs. 6 and 8). Most of the Cerro Gordo brachiopod fauna was described and illustrated by Hall (1858), Hall and Whitfield (1873), Fenton and Fenton (1924), Fenton (1931), and Stainbrook (1945), and Cooper and Dutro (1982). Cerro Gordo Member brachiopods (Table 1) are associated with a diverse suite of molluscs, bryozoans, echinoderms, cnidarians (corals), and poriferans (stromatoporoids). The general distribution of brachiopods in the intervals of the *Cyrtospirifer whitneyi* and *Elita inconsueta* Zones of Day (1989) are featured in Figures 7 and 8.

Owen Member

The Owen Member consists of limestones, dolomitic limestones, dolomites, and shales in surface exposures and the subsurface of north-central Iowa. The Owen ranges in thickness from 2-10 meters in surface exposures shown in Figure 6. The type section (Fig. 6, locality 5) is located west and south of Clay Banks (Hackberry Grove) in Cerro Gordo County. The precise location of the type section and other important Owen Member outcrops and quarry exposures are discussed in Lynn (1978). Diversity of the Lime Creek brachiopod diversity lowest in rocks of the Owen Member which were deposited in much shallower water than the underlying outer to middle shelf facies of the Cerro Gordo Member.

Owen megafossil assemblages are usually dominated by corals and stromatoporoids, although molluscs and brachiopods (*Cyrtospirifer*, *Strophonelloides*, *Douvillina*, *Pseudoatrypa*, and *Rigauxia*) are locally abundant. One of the more distinctive brachiopods found in the Owen is *Iowatrypa owenensis* which serves as a zonal index fossil, whose first occurrence in the middle part of the Owen defines the base of the *I. owenensis* Zone of Day (1989). Modern studies of this distinctive atrypid include those by Copper (1973) and Copper and Chen (1995). The Owen brachiopod fauna is listed in Table 1.

Independence Shale

As now restricted, the Independence Shale only includes deposits that comprise cave fillings of Lime Creek equivalents found in various locations around eastern Iowa. These deposits may or may not yield shelly faunas, and those that feature brachiopods, corals, and other macroinvertebrates are only known from the type area near the towns of Independence and Brandon in central and southwestern Buchanan County. Other deposits included in the Independence Shale (yielding late Frasnian conodonts) have been discovered the Iowa City area in Johnson County (*see* Witzke, 1984; Witzke and Bunker, 1994).

Stainbrook described most of the brachiopod fauna of the Independence Shale in a series of studies in 1935, 1942, and the monograph on Independence brachiopods in 1945. Cooper and Dutro (1982) described and illustrated a number of Lime Creek and Independence species, including *Nervostrophia extensa*. This distinctive species of *Nervostrophia* occurs in the Independence Shale and Amana Beds, and was first illustrated from Iowa as *Nervostrophia* sp. by Stainbrook (1945, Pl. 2, figs. 13-17).

The majority of brachiopods described from the Independence Shale also occur in the Lime Creek Formation of northern Iowa, although a number of taxa are restricted to the Independence Shale and the Amana Beds facies of eastern Iowa (Table 1). As mentioned above, both of these units are interpreted as having accumulated in deeper offshore settings in the Lime Creek-Sweetland Creek seaway, and consequently different groups of brachiopods dominate fossil assemblages found in these offshore deposits.

The most abundant elements of the Independence and related Amana Beds faunas are usually stropheodontids such as *Douvillina* and *Pseudodouvillina*, and rhynchonlellids such as *Calvinaria* and *Coeloterorhynchus*. This constrasts with the groups that usually are numerically dominant in Lime Creek assemblages atrypids (*Pseudoatrypa*, *Spinatrypa*), orthids (*Schizophoria*), and spiriferids (*Theodossia*, *Rigauxia*, *Cyrtospirifer*), with stroheodontids. "Deeper-water" species restricted to the Independence Shale or Amana Beds of eastern Iowa include: the orthids *Cariniferella iowensis*, *Schizophoria amanaensis*, *Skenidium independense*; the strophomenids *Pseudodouvillina euglyphea*, *Douvillinaria perversa*, *Nervostrophia extensa*, *Leptolosia inexpectans*; the terebratulid *Cranaena amana*; the atrypid *Costatrypa varicostata*; and the distinctive rhynchonellids *Hypothyridina emmonsi* and *Calvinaria ambigua*.

Amana beds

At its type section the Amana Beds consist of a 12-14 meter thick succession (see section description in Müller and Müller, 1957) of shales with minor thin bedded and nodular limestones in Iowa County (Fig. 4). The type section of the Amana Beds consist of a series of roadcut exposures located on the north side of Iowa Highway 222 immediately west of the village of Middle Amana (Fig. 4, locality 1). These exposures are now largely covered, and do not yield many fossils. Large collections from the Amana Beds are housed at the University of Iowa Paleontology Repository

TABLE 1. Early Upper Devonian (late Frasnian brachiopod fauna known from the Lime Creek Formation of north-central Iowa, the Amana Beds of Iowa County, and the Independence Shale of Benton and Buchanan counties, Iowa. Occurrence Key: Lime Creek Formation, JH=Juniper Hill Mb., CG=Cerro Gordo Mb., O=Owen Mb.; A=Amana Beds; IS=Independence Shale. All undescribed species are left in open nomenclature and are designated as such by the abbreviation n.sp.

	OCCURRENCE				
Class-LINGULIDA					
Lingula fragila Webster	JH	CG	-	-	-
L. sp.	-	CG	-	-	-
Class-INARTICULATA					
Petrocrania famelica (Hall & Whitfield)	JH	CG	O	-	IS
Philhedra sheldoni (White)	-	CG	O	-	-
Class ARTICULATA: Order-ORTHIDA					
Aulacella infera Stainbrook	JH	CG	-	-	IS
Cariniferella iowensis Stainbrook	-	-	-	-	IS
Rhipidomella n. sp.	JH	-	O	-	-
Schizophoria amanaensis Stainbrook	-	-	-	A	IS
S. iowensis (Hall)	JH	CG	O	A	IS
Skenidium independense Stainbrook	-	-	-	-	IS
Order-RHYNCHONELLIDA					
Atribonium prolifica (Belanski)	-	-	O	-	-
Calvinaria ambigua (Calvin)	-	-	-	A	IS
Navalicria n.sp. aff. *compacta* Sarternaer and Xu	-	CG	-	-	-
N. n.sp. aff. *rectagularis*	JH	-	-	-	-
Ripidiorhynchus saxatillis (Hall)	-	CG	-	-	-
Coeloterorhynchus calvini (Fenton and Fenton) =*C. schucherti* (Stainbrook)	-	CG	-	A	IS
Hypothyridina emmonsi (Hall & Whitfield)	-	-	-	A	IS
Order-STROPHOMENIDA					
Devonoproductus walcotti (Fenton & Fenton)	JH	CG	O	A	-
D. vulgaris Stainbrook	-	-	-	-	IS
Douvillina arcuata (Hall)	JH	CG	O	-	IS
D. n.sp.	-	-	O	-	-
Douvillinaria delicata (Fenton & Fenton)	-	CG	-	-	-
D. perversa Stainbrook	-	-	-	-	IS
D. variabilis (Calvin)	-	-	-	-	IS
Eostropholosia independensis (Stainbrook)	-	CG	-	-	IS
E. rockfordensis (Hall & Clarke)	-	CG	-	-	-
Floweria prava (Hall)	-	CG	O	-	-
Leptalosia inexpectans Stainbrook	-	-	-	-	IS
Nervostrophia calvini Stainbrook	-	-	-	-	IS
N. canace (Hall & Whitfield)	-	CG	O	-	-
N. extensa Stainbrook	-	-	-	A	IS
N. multinervosa Stainbrook	-	-	-	-	IS
N. rockfordensis (Fenton & Fenton)	JH	CG	-	-	-
N. thomasi Stainbrook	JH	-	-	-	IS
Productella rugatula Stainbrook	JH?	CG	-	-	-
P. thomasi Stainbrook	-	-	-	-	IS

		OCCURRANCE			
Pseudodouvillina euglyphea Stainbrook	-	-	-	-	IS
Retichonetes brandonensis (Stainbrook)	JH	-	-	-	IS
Strophodonta thomasi (Fenton & Fenton)	-	CG	-	-	-
S. n. sp.	-	CG	-	-	-
Strophonelloides reversa (Hall)	-	CG	O	-	IS?
S. (reversa) deeringeri (Stainbrook)	-	-	-	-	IS
Sulcatostrophia camerata (Fenton & Fenton)	-	CG	O	-	IS
Order-ATRYPIDA					
Costatrypa varicostata (Stainbrook)	-	CG	-	-	IS
Iowatrypa owenensis (Webster)	-	-	O	-	IS
= *I. americana* (Stainbrook)					
Pseudoatrypa devoniana (Webster)	JH	CG	O	-	IS
Spinatrypa rockfordensis (Fenton & Fenton)	-	CG	O	-	-
=*S. trulla* (Stainbrook)	-	-	-	-	IS
Spinatrypina n.sp.	-	CG	-	-	-
Order-SPIRIFERINIDA					
Cyrtina inulta Stainbrook	JH	CG	-	-	IS
C. iowensis Fenton & Fenton	-	CG	-	-	-
Order-SPIRIFERIDA					
Ambocoelia n. sp.	JH	CG	-	-	-
Acutatheca propira Stainbrook	-	-	-	-	IS
Cyrtospirifer whitneyi (Hall)	-	CG	O	-	IS
Elita inconsueta (Fenton & Fenton)	-	CG	O?	-	-
E. diversa (Stainbrook)	-	-	-	-	IS
Rigauxia orestes (Hall & Whitfield)	JH	CG	O	-	IS
Platyrachella macbridei (Calvin)	JH	CG	-	-	-
Tenticospirifer cyrtinaformis (H & W)	JH	CG	O?	-	-
Theodossia hungerfordi (Hall)	JH	CG	O	-	-
Thomasaria altumbonata Stainbrook	JH	-	-	-	IS
Tylothyris n. sp.	-	CG	-	-	-
aff. *T. sulcocostata* Cooper & Dutro					
Order-TEREBRATULIDA					
Cranaena calvini (Hall & Whitfield)	-	CG	-	-	IS
C. micula Belanski	-	-	O	-	-
C. navicella (Hall)	JH	CG	O	-	-
C. amana Stainbrook	-	-	-	-	IS
Order-PENTAMERIDA					
Gypidula cornuta Fenton & Fenton	-	CG	-	-	-
G. munda Calvin	-	CG	-	-	IS
G. n. sp. (!)	-	-	O	-	-

(Stainbrook and Belanski collections).

In 1993, new exposures of the Amana Beds were discovered along the banks of Price Creek about two miles north-northeast of the type section (Fig. 4, locality 2). Relationships of these new exposures to the type Amana Beds are shown in Figure 4. The Price Creek outcrops yield well preserved ammonoids (*Manticoceras*) in direct association with brachiopods (notably substantial numbers of *Calvinaria ambigua*), echinoderms (*Nortonechinus*), corals, and conodonts. Day (1995) correlated these new exposures with the *Elita inconsueta* Zone of the type Lime Creek based on the conodont and brachiopod faunas.

The composition of the Amana Beds brachiopod fauna is summarized in Table 1, and brachiopods recently recovered from the new Price Creek outcrops are discussed in Day (1995). Current correlations of the type Amana Beds and new Price Creek outcrops with the Lime Creek Formation are shown in Figure 5, and are discussed by Day (1995).

BRACHIOPODS IN THE TYPE LIME CREEK FORMATION

Collectively, late Frasnian rocks in Iowa yield as many as seventy-one species of brachiopods representing the three major classes of the phylum (Lingulida, Inarticulata, and Articulata; Table 1). The Lime Creek Formation of north-central Iowa yields at least forty-five species, including at least seven undescribed forms (Table 1). The general features of the faunas of each member of the Lime Creek are reviewed below. Readers interested in detailed information about stratigraphic and paleogeographic ranges of Lime Creek brachiopod taxa and related North American faunas should refer to additional papers by Drewes (1967), Beus (1978), Johnson and others (1980), Cooper and Dutro (1982), Day (1988b, 1989, in press).

Fauna of the Juniper Hill Member

As discussed earlier, the brachiopod fauna of the Juniper Hill Member is best developed in the subsurface of Cerro Gordo County (Table 1, Figs. 6 and 7). The Juniper Hill yields at least 20 species of brachiopods. A single phosphatic lingulid, *Lingula fragila* occurs in abundance, especially in the lower 2 meters of the Juniper Hill where it is the only known brachiopod in that interval (*Lingula fragila* Zone of Day, in press, Figs. 2, 5, and 6). This species ranges through most of the Lime Creek (Table 1, Fig. 7). The inarticulate *Petrocrania famelica* occurs as a fixosessile epibiont on shells of larger brachiopods in the Juniper Hill.

The Juniper Hill features new species of the widespread rhynchonellid *Navalicria*. This species is similar to *N. retangularis* described by Sartenaer and Xu (1991) from late Frasnian rocks in China. The two most common Lime Creek orthids first appear in the Juniper Hill. These are *Aulacella infera* and *Schizophoria iowensis*.

Strophomenids first appearing in the Juniper Hill include the stropheodontids *Nervostrophia thomasi*, *N. rockfordensis*, and *Douvillina arcuata*. The latter two species are especially abundant in overlying rocks of the Cerro Gordo Member. The chonetid *Retichonetes brandonensis*, first described from the Independence Shale by Stainbrook (1945), was recovered from the Juniper Hill by the author, as well as from the Sly Gap Formation of New Mexico (Day, 1988b, 1989). Productellids occur in the upper half of the Juniper Hill and include *Devonoproductus walcotti* and *Productella* sp.

Thus far, only a single species of atrypid brachiopod has been recovered in the Juniper Hill Member. This is the distinctive frilled atrypid *Pseudoatrypa devoniana*. Juniper Hill spiriferids include: a new species of the ambocoelid *Ambocoelia*; the cyrtospiriferid *Tenticospirifer cyrtinaformis*; the theodossid *Theodossia hungerfordi*, the spinellid *Rigauxia orestes* (formerly assigned to the genus *Indospirifer*, *see* Brice, 1988, and discussion in Day, in press); *Thomasaria altumbonata*; the distinctive spinocyrtid *Platyrachella mcbridei*; and the spiriferidinid *Cyrtinainultus*.

Fauna of the Cerro Gordo Member

The Cerro Gordo Member features at least 38 species of brachiopods (Table 1). Inarticulate brachiopods are generally inconspicuous, but com-

FAUNAL INTERVALS 13-18										
Brachiopod Taxa F.I.	13	14	15	16	17	18	**Brachiopod Taxa** F.I.	16	17	18
Lingula fragila	●	●	●				*Ripidiorhynchus saxatillis*	●	●	
Nervostrophia thomasi		●					*Douvillainaria delicata*	●	●	
Navicularia aff. N. rectangularis		●	●	●	●		*Gypidula cornuta*	●		
Petrocrania familica		●		●	●	●	*Nervostrophia canace*	●	●	●
Pseudoatrypa devoniana		●	●	●	●	●	*Tylothyris n.sp.*	●	●	
Tenticospirifer cyrtinaformis		●		●	●		*Strophonelloides reversa*	●	●	●
Devonoproductus walcotti		●	●	●	●	●	*Spinatrypa rockfordensis*	●	●	
Schizophoria iowensis		●	●	●	●		*Spinatrypina planosulcata*	●	●	
Nervostrophia rockfordensis		●	●	●	●		*Strophodonta thomasi*		●	
Ambocoelia n.sp.			●	●	●		*Coeloterorhynchus alta*		●	
Douvillina arcuata			●	●	●		*Elita inconsueta*		●	●
Productella cf. P. thomasi			●		●		*Floweria prava*		●	●
Retichonetes brandonensis			●				*Sulcatostrophia camerata*		●	
Rhipidomella n.sp.			●		●		*Cranaena calvini*		●	
Aulacella infera			●				*Eostrophalosia rockfordensis*		●	
Thomasaria umbonata			●				*Gypidula parva*		●	
Cyrtina iowensis			●	●	●		*Gypidula n.sp.*		●	
Rigauxia orestes			●	●	●		*Cranaena micula*		●	
Theodossia hungerfordi			●	●	●		*Atribonium prolifica*		●	●
Cranaena navicella			●	●	●		*Douvillina n.sp.*		●	●
Platyrachella macbridei			●	●			*Iowatrypa owenensis*			●
Cyrtospirifer whitneyni				●	●	●	*Strophodonta n.sp.*			●

Figure 7. Late Frasnian brachiopod sequence in Iowa Devonian Faunal Intervals 13 through 18, developed in the Lime Creek Formation of north-central Iowa. Brachiopod range data adapted from Day (1989a), ranges emended and Iowa Devonian Faunal Intervals (F.I.) defined in Day (in press-a.). Juniper Hill fauna included in F.I. 13-15, Cerro Gordo and Owen faunas included in F.I. 16-18.

mon elements of the Cerro Gordo fauna, and occur as closely cemented or attached forms on the surfaces of larger host species, usually other brachiopods or gastropods. *Philhedra sheldoni* will often mimic the features of the surface ornament of its host species as a form of camouflage, whereas *Petrocrania famelica* has a low conical ventral valve with simple concentric growth lines and fine radial costallate oranment, usually closely appressed to the shell surface of the host species.

Rhynchonellids are generally rare in the Cerro Gordo Member, and are represented by three genera. These include: *Ripidiorhynchus saxatillis*, *Coeloterorhynchus calvini*, and an undescribed species of *Navalicria*. The latter can commonly be found in the interval of the *Cyrtospirifer whitneyi* Zone at the Rockford Quarry (Fig. 6).

The orthid *Schizophoria iowensis* is abundant in the Cerro Gordo and ranges throughout the member. Because of its small adult size (10-12 mm), *Aulacella infera* is usually overlooked, but is found in the lower part of the Cerro Gordo. In general, pentamerids are rare in the Lime Creek. By the late Frasnian, only a single genus (*Gypidula*) occurs in most faunas in North America. If found, usually it is the larger of the two Cerro Gordo species (*G. cornuta*).

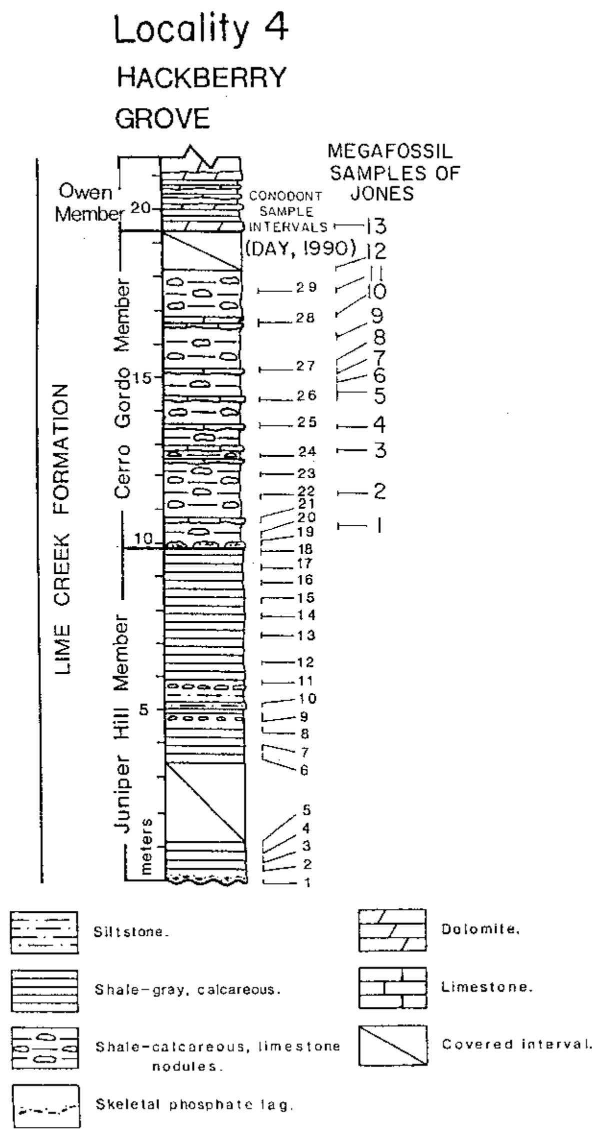
Strophomenid brachiopods comprise a significant proportion of the Cerro Gordo fauna. The most abundant are liberosessile (freelying-unattached) species of various stropheodontid genera including: *Douvillina arcuata*, *Sulcatostrophia camerata*, *Strophonelloides reversa*, *Nervostrophia canace*, and *N. rockfordensis*. Less common stropheodontids include *Strophodonta thomasi* and *Douvillinaria delicata*. Productids are abundant in the fauna, and include: the productellids *Devonoproductus walcotti* with radial costellae on its ventral valve, and *Productella* cf. *thomasi*; and the strophalosids *Eostrophalosia rockfordensis* and *E. independensis*.

The latter species is quite small and thin shelled, and was first described from the Independence Shale by Stainbrook (1945). This form was recently discovered by the author in the Belanski's Lime Creek collections (University of Iowa). Species of *Eostrophalosia* are usually cemented by their umbos to a hard substrate, as evidenced by the presence of ventral cicatrices (attachment scars) on the pedicle valves most specimens of both Cerro Gordo species. Another common fixosessile (cemented-attached) strophomenid found in the Cerro Gordo fauna is *Floweria prava*, with a fine radial costellate ornament, a planer dorsal valve, a inflated convex ventral valve, and commonly with a visible apical ventral cicatrix.

Atrypid brachiopods are particularly abundant in the Cerro Gordo fauna. The most common species is the frilled atrypid *Pseudoatrypa devoniana*, characterized by its numerous radial costae, and conspicuous regularly spaced concentric frill bases (frills rarely preserved). *Spinatrypa rockfordensis* is also abundant, and is easily distinguished by its less numerous low rounded costae, concentric lamellose growth lamellae, and variably preserved spine bases (spines are preserved on many specimens). An undescribed species of the closely related genus *Spinatrypina* occurs in the Cerro Gordo. This genus is easily distinguished from *Spinatrypa* by its smaller adult size, transverse posterior margin, and finer and more numerous radial costae and spines.

The Cerro Gordo yields a distinctive and superbly preserved suite of spiriferid brachiopods. Numerically, the most abundant taxa are: the spinellid *Rigauxia orestes* with its prominent plicate anterior commissure, and prominent medial costae on the fold and in the sulcus; and the theodossid *Theodossia hungerfordi*, with its finely costate radial ornament and highly reduced fold and sulcus and gently uniplicate anterior commissure. Other common spiriferids are the cyrtospiriferids *Cyrtospirifer whitneyi* and *Tenticospirifer cyrtinaformis*. The latter is easily distinguished by its pyramidal ventral valve, flat triangular interarea, poorly developed to absent medial sulcus and fold, and smaller size (up to 15 mm).

The distinctive and quite attractive spinocyrtid spiriferid *Platyrachella macbridei* is found in the lower part of the Cerro Gordo. This species is one of the last representatives of its family prior to the extinction of the group at the end of the Frasnian. This form first appears in the upper Juniper Hill, and ranges into the lower part of the Cerro Gordo,



	Brachiopod Zones (Day, 1989)												
	C. whitneyi			Elita inconsueta Z.									
	Megafossil Samples of Jones												
BRACHIOPOD TAXA	1	2	3	4	5	6	7	8	9	10	11	12	13
Cyrtospirifer whitneyni	●	●	●	●		●			●		●	●	
Rigauxia orestes	●		●	●	●	●	●	●	●		●	●	●
Tenticospirifer cyrtinaformis	●		●		●			●				●	
Theodossia hungerfordi	●		●	●	●	●	●	●	●	●	●		●
Gypidula cornuta	●												
Aulacella infera	●			●									
Schizophoria iowensis	●	●	●		●	●	●	●	●		●	●	
Devonoproductus walcotti	●		●		●	●		●		●	●	●	●
Nervostrophia canace	●		●		●								
Strophodonta thomasi	●		●	●	●								
Strophonelloides reversa	●						●					●	
Douvillina arcuata		●	●				●	●	●			●	
Ambocoelia n.sp.		●											
Pseudoatrypa devoniana		●	●	●	●	●	●	●	●		●	●	●
Spinatrypa rockfordensis		●	●			●			●		●	●	●
Cyrtina iowensis			●				●		●		●	●	
Sulcatostrophia camerata			●				●		●		●	●	
Douvillainaria delicata			●									●	
Elita inconsueta					●						●		
Cranaena navicella						●	●					●	
Floweria prava												●	
Coeloterorhynchus calvini									●		●	●	

Figure 8. Stratigraphy of the Lime Creek Formation and positions of conodont and brachiopod samples at the Hackberry Grove (Clay Banks) locality is shown on the right (locality 4 on map of Fig. 6). Chart on right shows ranges of selected brachiopod species identified by the in samples of Jones collected with the author in the summer of 1987.

and is commonly found at the Rockford Quarry in the fauna of the *Cyrtospirifer whitneyi* Zone (Figs. 6 and 7). The reticularid *Elita inconsueta* is the nominal species of the *E. inconsueta* Zone (Day, 1989; Figs. 2, 5, and 6) of the Cerro Gordo Member of the Lime Creek, and is usually a rare but important element of the Cerro Gordo fauna. Rarely encountered is an undescribed species of the delthyrid *Tylothyris*, that occurs in the basal Cerro Gordo at the Rockford Quarry, and ranges into the upper part of the member at Bird Hill. Larger adult specimens of *Tylothyris* n.sp. (15-20 cm) may be easily mistaken for certain medium-sized specimens of *Rigauxia orestes* that may lack well developed medial costae. Ambocoelids occur as rare components of the Cerro Gordo fauna as represented by the same undescribed species of *Ambocoelia* that first occurs in the older Juniper Hill fauna. Terebratulids are another group commonly encountered in the Cerro Gordo Member fauna. A single short-looped genus *Cranaena* is represented by four species in the Cerro Gordo (Table 1). The most common and largest of these is *C. navicella*. Large adult specimens of this species may reach lengths of 70-80 mm, which is gigantic by late Devonian terebratulid standards, and larger than nearly any other species of Lime Creek brachiopod.

OWEN MEMBER FAUNA

The Owen Member brachiopod fauna includes at least 20 species, most of which carryover from the older Cerro Gordo fauna. The entire Owen fauna in listed in Table 1, although only species recovered in my samples are shown in Figure 7. The more important elements of the Owen brachiopod fauna were outlined in the preceeding section of the stratigraphy of the Owen, and readers are referred to that discussion.

ACKNOWLEDGMENTS

I would like to thank Leslie Jones (formerly of Cedar Falls) for allowing the author to publish her data on the brachiopod sequence developed in the Lime Creek at Hackberry Grove.

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STOP 2

GEOLOGY AND HISTORY OF THE LITHOGRAPH CITY QUARRIES

LITHOGRAPH CITY — HISTORICAL OVERVIEW

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INTRODUCTION

Before printed books, certain aspects of culture such as history, laws, and church were preserved only by memory. The first manuscripts were hand-written on papyrus sheets which were glued together and rolled up. The rise of mechanical printing techniques involved blocks of wood, raised type molded of metal, or images engraved into wood or metal. With the advent of movable type and the production of bound pages, the written word has become more accessible to the general population.

Near the end of the 18th century, the technique of lithography was invented by a young Bavarian playwright, Aloys Senefelder, who sought an inexpensive means of reproducing his scripts. He found that text could be reproduced from smooth slabs of dense, fine-grained limestone inked with a preparation of wax, soap, lampblack and water. Lithography, as this process came to be known, is derived from the Greek words for "stone" and "writing." It is based on the concept that grease and water will not mix, and that greasy inks will adhere to an already greased surface while unmarked areas will remain clean provided the stone is kept damp during the operation.

Many types of limestone have been used in lithography, but the world's best lithographic stone has traditionally come from quarries near the town of Solnhofen in the Jura Mountains of Bavaria (Germany), where the Senefelder family lived. These deposits of Jurassic-age limestone are superior because their fine granularity and chemical purity produce stable and consistent reactions in the process of drawing and printing. Vast quantities of these stones, cut and prepared in a variety of sizes, were shipped to the United States during the 19th century for use in commerical lithography.

LITHOGRAPH CITY

Many northeastern Iowa residents today recall the story of Lithograph City - the town that romance built. The story dates back to near the turn of the 20th century when a young geologist, Clement L. Webster of Marble Rock, Iowa., was courting Libby Rumsey, who lived on a farm north of Floyd, Iowa. On one of their strolls through the hills, Webster discovered unusual stones.

His geologist's insight told him that the rock had special qualities. He took samples home and launched his own laboratory tests; in the end he became convinced that the stone was of the same kind as that believed to exist only in Bavaria, and hence was suitable for use in lithography. In the 1903 Annual Report of the Iowa Geological Survey, Samuel Calvin noted that samples of Iowa's lithographic stone were submitted for testing to the lithographing house of A. B. Hoen & Company of Baltimore, Maryland. Hoen's "Discussion of the Requisite Qualities of Lithographic Limestone, with Report on Tests of the Lithographic Stone of Mitchell County, Iowa" was also published in this volume. This report includes a color plate (VII) printed on a sample stone from Mitchell County.

Webster saw in an American source of lithographic limestone a great opportunity. He was determined to launch a settlement on the site and market the stone for monuments and lithograph work. He founded a company, *"the Interstate Investment and Development Company,"* with himself as president. The land was purchased, 240 acres at first, then another 160, and on June 10, 1905, Lithograph City was platted (Lithograph City was reportedly surveyed by G.H. Elliot in May, 1906; the fact that this survey comes almost a year after the report of platting in 1905 suggests an error in the town's available history, however the filing of the plat did not seem to occur until 1908 as noted on the plat; see figure). The plat shows six avenues running north and south, and four streets running east and west: *Main, Lithograph, Rock and Brick* streets.

... "about 1907," ... "They had a big tent and speakers and sold pieces of shares. They had a big crowd." But despite the push to sell stock and raise money, the company was unable to get a financial start until the spring of 1913, when one account said that "everything was in readiness for a forward movement of the enterprise." By then two houses had actually been built and Webster is said to have expected 100 more to go up. About $50,000 worth of quarrying and stone processing machinery was ordered that year. To haul away the stone, Webster sought a spur track from the main line of the Milwaukee Railroad. That was never to come. Instead, when quarrying began, the stone was taken to a farm-tractor powered "train" which pulled steel wagons to the town of Orchard. The same vehicles transported lumber and building materials to Lithograph City for construction of houses and businesses.

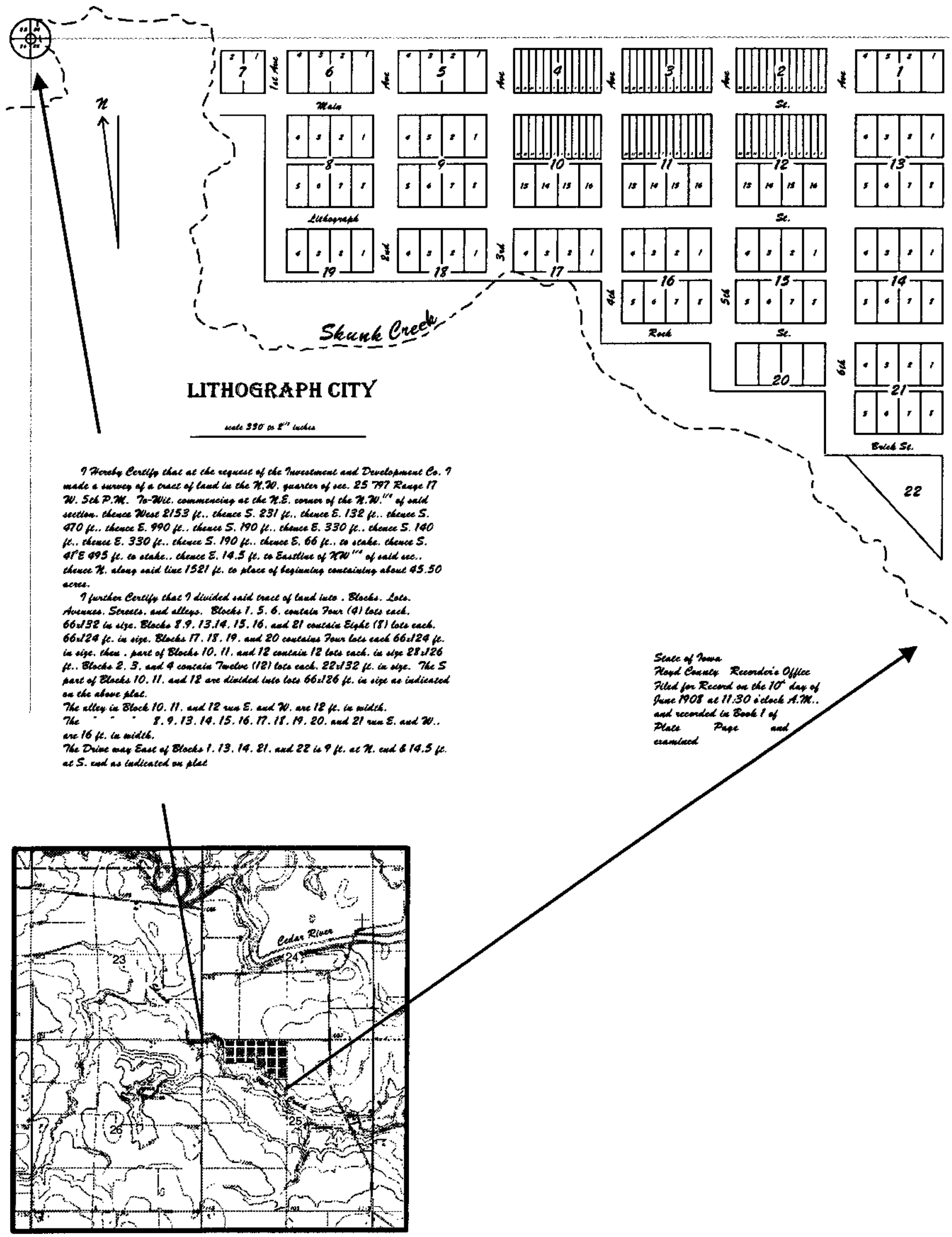
Clement Webster himself published a journal called Contributions to Science, and the June, 1915 edition is devoted to "Lithographic Stone at Lithograph City, Iowa" and includes 31 photographs, plates, and endorsements from the lithographing companies. Webster recounts that in 1903 the Interstate Investment and Development Company of Charles City submitted samples of stone from its Lithograph City quarries to the Iowa Publishing and Lithographing Company of Davenport, Iowa. This firm reported the stones's quality as equal to the best German stone for high-grade lithography and placed the material on exhibit at the Louisiana Purchase Exposition in St. Louis. These stone products from the Lithograph City quarries were judged in open competition by an international jury and took the gold, silver, and bronze medals as well as the Grand Prize Award. A printed lithograph stone is currently on display in the Floyd County Historical Society Museum, in Charles City, Iowa.

Webster found backers for his adventure throughout northeastern Iowa, and by 1915 Lithograph City included 15 houses, had several more foundations, a hotel, blacksmith shop, stone polishing plant, museum, lumber yard, general store and dance hall. The onset of World War I curtailed the importation of Bavarian stone, and the operation at Lithograph City was expanded to meet the anticipated demand for quality stone.

However, the town's financial backers broke into discord. One historical account said, "Many town lots were sold at first and a real boom started, but litigation between members of the company has hindered development of the embryo city." Operations at the quarry came to a halt. It was even called a mere "promotion scheme," and there were rumors and accusations that the directors of the company had embezzled its funds.

So it all collapsed. A new company was formed to produce crushed rock and related products. It issued new shares of stock, operating under the name, "The Devonian Products Company." One of the company's stock certificates, showed the company selling shares for 25 cents and issuing $100,000 in stocks. Understandably, the loss of a market for stone prompted a change in the name of the town from Lithograph City to Devonia, but the change in name brought no change in the town's ill fortune. The new company failed, just as the first had. The machinery from the rock plant was sold as junk iron. Efforts to establish a post office failed. Stores closed and families moved away. The houses and buildings were to move away too. It became a custom that when farm houses burned in the area, farmers would buy a house in Lithograph City.

By 1938 Lithograph City (Devonia) had been thoroughly "plowed under." The sounds of a banjo, cash register and of stone being cut have long faded. A half century later Devonia is like the fields around it, given over to pasture and corn. Cattle graze around sidewalks and cellar holes. They chew on grass at the edges of pieces of peculiar white stone which would seem to polish up to a fine smoothness. A deteriorating obelisk of lithograph stone stands today at what was the corner of 3rd Avenue and Lithograph Street, just to the southwest of the Webster museum. Because the speculators' dream fizzled the town acquired a third name of Fizzletown before it became pastureland again.



1908 map from the Floyd County Recorder's Office of the platting of Lithograph City, Floyd County, Iowa.

GEOLOGY

It has long been accepted as an undisputed fact that a proper geological survey of a state or a country, would prove of inestimable value, not only to that region and its people, but to many others located outside that immediate locality. Such a survey points out what resources do not occur and for which search should not be made and expenditures incurred, but also shows to the public the extent, value and importance of the natural resources of the region which actually do occur there, together with the best methods of developing the same. Without this knowledge which a geological survey would reveal, their natural resources would remain unknown and undeveloped.

During 1985 and 1986, geologists with the Iowa Geological Survey Bureau redefined the stratigraphic framework of Devonian aquifers in Floyd and Mitchell counties, and they recognized widespread, repetitive patterns of lithographic limestones in this part of the state. They gave the name Lithograph City Formation to this distinct sequence of rock (part of the Cedar Valley Group) and established its type-section at the old quarry exposures near the historic site. To date no studies have been undertaken to evaluate the printing characteristics of the additional lithographic stone in Iowa.

SUMMARY

Today the stone, chemicals, inks, and papers of lithography are largely the craft of artists and artisans-printers. In 1960, the Tamarind Lithography Workshop Inc. was established in Los Angeles under a grant from the Ford Foundation for the purpose of providing a new stimulus to the art of lithography in the United States. In 1968, a representative of Tamarind Workshop visited Iowa to evaluate the potential of using stone from Lithograph City. Preliminary results indicated that its quality compared very well with Solnhofen stone, as had been determined early in the century. In the course of their studies, however, it was discovered that white onyx could be used as a substitute, and its availability in large quantities and slab sizes for relatively low cost, combined with the costs of reopening the quarries at Lithograph City, essentially removed Iowa from further consideration.

In the section that follows are a series of selected newspaper clippings from a variety of northern Iowa communities, presented in newspaper style format under the banner — "The Lithograph City Enterprise." The Lithograph City Enterprise newpaper operated during the approximately 18 months that Lithograph City existed, after which it apparently folded. The following clippings summarize the initiation, financial problems, and demise of Lithograph City, its holdings and patrons.

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The Lithograph City Enterprise

VOLUME 3 LITHOGRAPH CITY, FLOYD COUNTY, IOWA, SATURDAY OCTOBER 28, 1995 NUMBER 1

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LITHOGRAPH CITY

A New Town Surveyed In Floyd County

It will perhaps be news to many that a new town has been platted in Floyd county, six miles south of Osage, where Prof. Webster recently discovered a deposit of lithographic stone, and it is the prediction of the company having the enterprise in charge that it means a town of rapid and permanent growth. To this end the company has issued about 10,000 circulars announcing the sale of town lots on June 15th, when it is confidently expected that there will be a large number of people present to buy business and residence lots and profit by the development of the lithograph quarry in which the promoters have every confidence, predicting in five years a population equal to Charles City. The propectus gives the following sketch of the town:

> The town site is beautiful, nearly level, situated on two of the main highways and in the midst of a prosperous and thickly settled part of Floyd county. Careful attention has been given to laying out the town. The main business street is 66 feet wide. The business lots are 25 feet wide, 132 feet long and 12 foot alleys. All residence streets are 66 feet wide, and the lots are 50 x 130 feet, and 16 foot alleys. There is now here on this new site a nice M.E. church edifice, the company's branch office building, a good lumber yard, etc., and numerous wide-awake and energetic buisness firms pledged to begin business right away.

Terms will be in readiness at Orchard (on Illinois Central railway, three miles north from Lithograph City) to convey parties desiring to visit Lithograph City on the sale day, June 15th.

Over one hundred visitors registered at the museum last Sunday, and it seemed as tho "all roads led to Lithograph City."

Charles City Herald - January 22, 1908

LITHOGRAPH CITY CASE

The Lithograph City injunction case heard before Judge Reed of the U. S. district court at Dubuque last week, in which defense raised the question of jurisdiction of the court to entertain the case, the attorneys were given a week in which to prepare and present their briefs and arguments. Most of our readers are familiar with the case. The corporation known as the Interstate Investment and Development Co., organized about four years ago in this city, the object of which was to promote and develop different enterprises, finally resulted in the lithograph quarry north of town. The stockholders are scattered all over northern Iowa and Wisconsin. Two years ago the principal office of the corporation at Charles City entered into a contract with a New York corporation organized under the laws of the District of Columbia to transfer the property to New York. It is alleged this contract was entered into with the New York company by the directors of the Charles City corporation without the knowledge and consent of the stockholders.

The capital stock of the New York corporation was ten million dollars. The stockholders of the Charles City corporation were dissatisfied and notified the directors to get back the property. The New York corporation deeded back the real estate, but had received about $15,000 from the Iowa company, which, it is alleged was not returned. The present action of the Iowa company is to compel the New York corporation to transfer the stock back to the Iowa company and pay back the money the Iowa directors, it is alleged, had paid over to the New York corporation.

The delay in the decision was brought about at the request of complainant stockholders, pending the preparation of a brief, which constitutes the furnishing of a rebuttal argument of the complainant stockholders. Details will be given the public as soon as a decree of the court has been rendered, which is expected in ten days or two weeks.

"Wonderful and beautiful" was the expression of Mrs. C.N. Wells of Ayrshire, Iowa, after touring the museum Sunday.

Charles City Herald - March 25, 1908

Decree In the Interstate Investment and Development Company Case

Because of the importance and far reaching effect of the findings of the United States court in this case, and also because of its deep interest to many here and elsewhere, we below print a copy of this decree recently received. It will be observed that in some respects it is more severe on the defendants than was at first reported in this and other papers here.

DECREE IN EQUITY

In the Circuit Court of the United States, Northern District of Iowa, Eastern Division.

Thomas J. Fraggart, Abram W. Hicks, Joseph W. McLaughlin, William B. Latham, et al.

vs

Charles F. Morris as president, Chester E. Sheldon as secretary, George W. Von Berg as treasurer and Frank E. Hirsch, Charles F. Morris, Geo. W. Von Berg, H.L. Lockwood and Chester E. Sheldon as directors of the Interstate Investment and Development Company, and Charles F. Morris, Frank E. Hirsch, Geo. W. Von Berg, Charles E. Sheldon, and H.L. Lockwood, each in his individual capacity.

Now on this 3rd day of March, 1908, this case having heretofore been fully argued and submitted to the court, and taken under advisement, it is ordered, adjudged and decreed as follows, to wit:

That all of the payments made or authorized to be made by the defendents, Charles F. Morris, Frank E. Hirsch, George W. Von Berg and Charles E. Sheldon, as directors of the Interstate Investment and Development Company, out of the funds of said corporation for and on account of the Charter of the Radio Company, so called, and the transfer of any and all funds of said corporation to said Radio Company, and all expenses connected with the procuring of said charter, the organizations of said company, the equipment and furnishing of offices therefore, etc., and paid out of the funds and moneys of said corporation, were made and procured without authority of law, beyond the rightful power of said defendents, active for and as the board of directors of said corporation, and in fraud of its rights and of the rights of its stockholders, and it is adjudged and

THE LITHOGRAPH CITY ENTERPRISE
FOUNDED 1916
HARRY L. SWAN, Manager

Issued Every Thursday at Lithograph City, Iowa, by the Interstate Investment and Development Company Office at Corner Main Street and Third Avenue

Subscription Price $1.50 per Year
Advertising Rates Upon Application

decreed that plaintiff's herein have and recover of all of said defendants, jointly and severally, payment in the sum of fifteen thousand eight hundred forty-one dollars and nineteen cents ($15,841.19) for the use and benefit of said Interstate Investment and Development Company, together with interest thereon as follows, to wit: Interest at six per cent per annum upon the sum of thirteen thousand five hundred sixty dollars and ninety cents ($13,560.90) from December 19, 1906; interest at six per cent per annum, upon the sum of one thousand twenty-five dollars and five cents (1025.05) from November 4, 1906; interest at six per cent per annum upon the sum of one hundred five dollars and twenty-four cents ($105.24) from January 16, 1907; interest at six per cent per annum upon the sum of one hundred fifty dollars ($150) from February 6, 1907; interest at six per cent per annum upon the sum of one thousand dollars ($1000) from May 22, 1907, and execution may issue to enforce such judgment.

It is further adjudged and decreed that of said sum of fifteen thousand eight hundred forty-one dollars and nineteen cents ($15841.19), hereby entered and declared to be a judgement against the defendendants, herein before named, to wit: Charles F. Morris, Frank E. Hirsch, George W. Von Berg and Charles E. Sheldon, plaintiffs, have and recover judgement against the defendant, H.L. Lockwood, for the sum of one thousand dollars ($1000) only with interest thereon at six per cent from the 22nd day of May, 1907, and execution is awarded therfore.

It is further appraised and decreed that the certain ten thousand six hundred sixty-six and two-thirds shares of the capital stock of said corporation, being and, including the shares of said capital stock known as the Korinke and Leland stock, two thousand six hundred sixty-six and two-thirds shares of which were illegally assumed to be owned and taken over by each of the defendants, Charles F. Morris, Frank E. Hirsch, George W. Von Berg, and Chester E. Sheldon; and also thirty-two thousand shares of said capital stock, eight thousand shares of which were without authority issued to and taken by each of said defendants as promoters stock, so called, be cancelled and annulled, and decreed to be void and of no effect, and it is further adjudged and decreed that the voting of said forty-two thousand six hundred sixty-six and two-thirds shares of capital stock by said defendants at the annual election of the stockholders of said corporation on the 17th day of June, 1907, was illegal and unauthorized, and the election of directors and officers of said corporation thereof to-wit: Charles F. Morris, Frank E. Hirsch, George W. Von Berg, and Chester E. Sheldon, Charles A. Lautsky and Charles A. Jordan, is hereby set aside, and declared to be null and void; and any three or more of the complainants are hereby authorized to call a special meeting of the stockholders of said corporation to be held at some convenient and suitable palce in the city of Charles City, Iowa, on a date to be fixed by them, for the election of a board of directors of said corporation, and shall give written notice of the date, hour and place of such meeting and purpose thereof, by mail to all stockholders of record of said corporation, at least ten days before such meeting; and at such meeting no part of said forty-two thousand six hundred sixty-six and two-thirds shares of the capital stock herein before adjudged void shall be voted; and the board of directors so elected at such special meeting shall act as the board of directors of such corporation until the next annual meeting of its stockholders, and until their successors are elected, and the defendant or defendants having custody of the stock books or record of the stockholders of said corporation shall furnish to the complainants or any of them full and free access to such books or records to enable them to obtain the names and addresses of the stockholders of said corporation in order that they may give proper notice of such meeting.

It is further adjudged and decreed that the injunction heretofore issued out of this court against said defendants, is made perpetual, and the said defendants, Charles F. Morris, George W. Von Berg, Frank E. Hirsch, Chester E. Sheldon, H.L. Lockwood, Charles A. Lautsky and Charles A. Jordan are perpetually restrained and enjoined from exercising any function as directors and officers of said corporation, under and by virtue of the election of the stockholders at the annual election thereof on June 17, 1907, and that plaintiff have and recover of the defendants costs of suit. To which judgment and decree and every part thereof defendants accept.

Charles City Herald
April 22, 1908

SEARCH FOR MISSING WOMAN

Dubuque Party in the City in the Effort to Locate Her.

Mr. Bigelow, of Dubuque, accompanied by a party of seven, arrived in the city last evening in search of Mrs. Blanche Schoeuthal, who has been missing from her home since last Friday, and so far all efforts to locate her have proved fatal.

It seems that she invested $1000 in the Lithograph City enterprise, and recent events having convinced her that the proposition was unprofitable, she had apparently brooded over the matter until her mind had become unbalanced and was wandering aimlessly over the country; and after failing to find her in the vicinity of Dubuque, they thought she had probably journeyed to Charles City in the hope of recovering her money.

In company with Sheriff Schermerhorn, Mr. Bigelow drove out to the lithograph quarry this afternoon in the hope of finding some trace of her wanderings.

Mrs. Schoenthal is said to be a woman of about 40 years of age, five feet six inches tall, and weighing about 150 pounds. She had a round, full face, hair of the brunette type and a good carriage.

Charles City Daily Intelligencer
June 16, 1914

The directors and stockholders of Lithograph City are in session today, a large number coming to this city this morning, and driving to the townsite by auto, while still others went on to Orchard and returned from there. This is the annual business meeting, and as this project seems to have proven itself of late more than a mere figment of the imagination it is thought that during the meeting today, many steps will be taken toward developing the project. It is thought that over one hundred out of town stockholders would be present beside the local people interested and plans had been made for the entertainment of the visitors during the day at the town site north of Floyd.

Lithograph City Enterprise
June 8, 1916, vol. 1 no. 1

MANY IMPROVEMENTS NOW UNDER WAY AT LITHOGRAPH CITY

A Railroad is Projected and is Expected to Build Soon

POSTOFFICE IS IN SIGHT

Up-to-date Newspaper Plant is Established and Ready for Business

At the present time our town has no railroad facilities, altho offering every inducement for one to build in, as we can offer a greater tonnage than can many ordinary places usually found located along a railroad. However it is assured we will, in due time, secure a railroad for our city and then we will have one of the most energetic and thriving business places in Northern Iowa. At present there is one railroad located two miles east, two located six miles north, one located six miles south and several located to the west. More relative to this matter will appear in these columns later.

We are to have a postoffice for our new city and later a full announcement relative to this subject will be made. Already there are several aspirants for the office of postmaster when the time is ripe, all of whom possess merit and ability.

The value and importance of printers ink when judiciously and properly used has long been so well known and understood that nothing special along this line need appear here save to say that every live town, the small and the new, possessing high hopes, ambition, courage, good backing and common sense, could hardly be held excusable if it did not possess the means of making known to the world what it and its people possessed of merit and real worth, both to itself and to others.

Imbued with these general ideas, we have established at Lithograph City a fine, well equipped and up-to-date newspaper and job plant where our friends are invited to call upon us. This office is equipped with a fine seven column quarto, Hoe cylinder press, a 14 1-2x22 Chandler & Price, New Series platen press, a Chandler & Price cutter, a dryer, and other high grade equipment, including a large assortment of job and newspaper type. Here the finest grade of work along all lines will be turned out and we are prepared to make our newspaper a credit to any community and to aid the public in every legitimate way.

The Lithograph City Enterprise will be under the general management of Mr. Harry L. Swan, late of New Hampton, who, with his genial wife, have arrived and taken charge of their new work and will take up their residence among the good people of our new city, who welcomes them to our midst.

Mr. Swan, although not "an ancient one" is yet a veteran, up-to-date printer and newspaper man and one who will make good in his new field. It will require some little time to get all the machinery "running smooth" in our new office, but this is the case always where you build from the foundation.

The History of Lithograph City, Iowa

The history of Lithograph City, past and present, is unique in many ways and when it shall have been written, will read, especially in the future, like a romance.

Far, far back before the advent of the white man and extending even back toward the sunrise of time as man's history goes, the low-browed and dark-skinned people of the stone age, whom we call the mound-builders, dwelt here and called it their home and of their occupancy have left many records of absorbing interest. ... This merging here of the present with the immeasurable past, becomes necessary, as the very life and existence of our fair young city is dependent upon the history which old Nature wrote upon the rocks here in that far distant time. When this history has been run we then, to finish it, must come back to the period of the stone age, then to the period of the pioneer time and end just where we began.

Lithograph City

Lithograph City is situated in the ancient and beautiful valley of the Cedar, where history runs back many thousands of years into the distant past. Here the Cedar once flowed, but now, in its comparatively new channel, almost encircles this place from the north to the southeast. Close by runs a little, meandering creek which, in the old days, was a paradise for the trapper.

All has been builded in best and most substantial manner, and is up-to-date in every way. The finest materials have been secured and the best workmanship possible obtained. The streets are wide and the cement sidewalks ample. All are required in building to adhere to a plan followed by all, which creates a uniformity both important and pleasing to see. The place is planned for the future as well as the present and the foundation has been well laid. Without a single exception the citizens here are of the highest type, progressive, educated, successful and aspiring to the highest and best. Such people laugh at obstacles and surmount all difficulties.

For the one who loves a beautiful place, with a history that is fascinating and a future bright with promise, this young city is ideal, and those who come to visit leave it with regret.

A feature especially important is the purity and inexhaustible supply of its water resources. Here also occur numerous living springs and a little lakelet.

This place too is situated in the midst of one of the finest and most beautiful farming regions of the state and is densely populated by a high and wealthy class of people who would be credit to any region.

Lithograph City as a Fishing Ground and Pleasure Resort

The Cedar River is one of the largest and most famous streams in Iowa and it has justly earned its fame as "The Beautiful Cedar." Along the stream, from Minnesota southward are almost innumerable places and regions presenting a solemn to a romantic beauty and it was never truer of any region than that along its course adjoining our new city. The topography of this region is often broken and rugged, with wooded sections along most of its way and little valleys and meandering streams uniting at frequent intervals. Here too, at Lithograph City, are fishing resorts equal in many ways to any known by the writer to exist elsewhere in Iowa. Picnicing, fishing and camping grounds are in existence at many places and in a modified way might

Public Museum at Lithograph City- This is purely an educational institution and one especially appreciated by the general public, to whom it is always open and free. The monument shown at the left is constructed of lithographic stone and marbles which for many thousands of years have been subjected to weathering agencies, and yet well maintains it own.

almost be called the Switzerland of America.

Clement L. Webster, M. Sc.

Mr. Webster, who is a professional geologist and mining engineer, was the discoverer of the wonderful products, which has made possible and advisable the establishing of Lithograph City. This discovery was made by him some thirty or more years ago. He is also the originator and founder of The Interstate Investment and Development Company and is its president and treasurer. His schools have been the district school, graded school, Iowa City Academy and the State University of Iowa. He long has been recognized as one of the foremost scientific men of this country and his published reports and papers are many. He has been unusually successful in business affairs and has a splendid standing in the commerical world. He is a member of most of the great scientific societies and is well versed and proficient.

Mr. Webster is strictly a self-made man, having been born in this country in pioneer days and for many years his home was on the farm. The log cabin in fact was his birth place, around which the Indians camped in numbers. It was through deprivation and hardships he fought his way unaided to the front and today he knows no obstacle he will not surmount. He is a careful and conscientious man, but when he is once assured of the correctness and advisability of a thing, then difficulties but become stepping stones to the accomplishment of the purpose. His experience as a geologist and mining engineer is extensive and but few know the western half of the United States and portions of Canada and Mexico so well as he. He has high and far reaching ambitions for the future educational and commerical advancement at Lithograph City, and the really great museum he has builded here will yet stand as a monument to his life's work.

The Museum

Existing at Lithograph City is a feature not known to me to exist elsewhere in this country in a new place. I refer to the Public Museum which has been established here. This is distinctly an educational and scientific institution and one which is creating great interest. As many as three hundred and twenty-five visitors per day have been admitted and during the very few months it has been opened to the public some 5,000 visitors have attended it. They have expressed themselves as greatly surprised and pleased with the many and beautiful exhibits shown there. It has, in fact, distinctive features not to be found elsewhere.

This building has been erected with an eye to its interior beauty and permenancy. Its dimensions are 22x50 feet, two stories, with a 50 foot concrete basement. Every foot of available space is taken up by splendid glass exhibit cases, all crowded to overflowing, with space for not much more than one-half the valuable educational material now on hand. In the lower rooms the cases are crowded with thousands of beautiful examples of cut and polished marbles, lithographic stone and gems from this place, together with large numbers of the finest marbles of the world, and beautiful fossils, etc. from other places.

It is an education to visit this one room alone and see what old Nature in her wonderful workshop has done. This chance for an education is free for no charges whatever are made.

As we ascend to the second floor we see displayed in the various cases, great numbers of strange and beautiful forms of nature, representing almost every division of natural history, until one becomes almost bewildered. The old ocean forms, from the sponges up to the vertabraes, are shown; the great fossils of the cretaceous and the rocks of other ages are seen. The rich gems of earth, minerals and crystal forms and the different species of animal life that inhabit the world around us are here. All this presents a scene not to be forgotten. In another issue of the Enterprise the different divisions of this wonderful institution will be described more fully.

Here also is to be established a free soil testing station, a feature rarely to be met with elsewhere.

This splendid institution is the beginning of the fulfilment of a far-reaching educational movement rarely undertaken by any one.

Unknown paper, 1913

FORWARD MOVEMENT AT LITHOGRAPH CITY

PRESIDENT WEBSTER SAYS AT LEAST 100 DWELLINGS WILL GO UP

HOUSE ARE FOR WORKMEN

$50,000.00 Worth of Machinery Ordered For Proposed Plant

Clement L. Webster, president and manager of the Interstate Investment & Development Co., better known as the "Lithograph City" enterprise, said yesterday in the course of a talk with a reporter for this paper that everything was now in readiness for a general forward movement in developing what he considered the greatest natural deposit of wealth in Iowa.

When pressed for a more explicit statement Mr. Webster said that work had already begun in building "Lithograph City" and that before the present season closed he expected to see at least 100 dwellings erected on the town site. Two buildings are already finished and cellars for a number more excavated.

According to Mr. Webster the matter of building dwellings for workmen is but a necessary secondary matter. The main purpose and aim of the company is to establish a great plant for the production of lithograph stone and such by-products as lime, nitrates, fertilizer and cement. Mr. Webster asserted before the board of supervisors yesterday that not less than $50,000.00 worth of machinery had been ordered for the proposed plant and that several large buildings would be erected in which this machinery would be installed.

Mr. Webster's chief concern at this time seems to be the fact that the bridge over the Cedar river near Orchard is not safe for heavy traffic. Mr. Webster stated that on account of the scarity of teams in the neighborhood his company has had to resort to a traction engine to do the hauling from Orchard station to "Lithograph City." By so doing it was found that the old bridge would not stand the strain in its present state of repair, hence he asked that it be put in shape so that the work might be prosecuted without delay. Mr. Webster intimated that hundreds of car loads of building material would be delivered at Orchard within the next twelve months and that the way must be made clear for its transportation to the plant site, else all work would have to be suspended.

In speaking more at length Mr. Webster said that as soon as a suitable showing was made at "Lithograph City" that a railroad or two would reach the spot. When pressed for their names he said that they could not divulged at this time. Mr. Webster said that home troubles had delayed the development of this great deposit of natural wealth for four or more years but now everything was in good shape with sufficient money in the treasury to do business on a large scale. He said that he did not desire or court opposition but that if such did develop it would make no difference with "Lithograph City."

In closing Mr. Webster said "the people of Charles City, Floyd county and the state of Iowa will see great things accomplished here during the present year. The enterprise..."

"AFTER FIFTY YEARS" (Dr. Pitts; published in the Lithograph City Enterprise, June 29, 1916)

Once more I stand by the church in the wildwood
Once more I wait at the wide open door,
Hearing the songs I loved in my childhood,
Thinking of those who have gone on before.
Here in this valley, near to the wildwood,
Bravely they wrought and nobly they won.
Now they are sleeping, quietly sleeping,
Fathers and mothers, sisters and sons.

Lithograph City Enterprise
July 28, 1917

HEFELE'S REPLY TO WEBSTER

Lithograph City, Iowa, July 28, 1917.
Editor Press:

Dear Sir: Referring to the article that appeared in your paper on July 25th relating to the information filed against Clement L. Webster charging him with larceny by embezzlement, I believe it fair to myself and the Interstate Investment and Development Company that due answer be made to Mr. Webster's article in order that no misapprehensions arise in the popular mind.

Mr. Webster in no way answered the charge against him. He did not answer it in Justice court. He waived examination and thereby directed the case brought by the state to go directly to the district court. If his hands are clean, why did he waive examination? It is most logical to assume that a man will meet a charge at once and save his name if he is in the clear, rather than send a cause before the grand jury. Nor did he answer or explain that charge in your paper. He hasn't explained it in any way whatever.

The simple fact remains that there was amply reasonable ground for the filing of such information. At any rate the case will not be tried in a newspaper, and Mr. Webster should be satisfied with a proper determination of the matter before a proper tribunal.

Such libelous statements made in the aforesaid article in my regard will also be passed upon by component minds. "Irresonsibility" is a relative term and Mr. Webster may not have used it in contemplation of his own individual standard.

Referring to Mr. Webster's statement that the Interstate Investment and Development Company is now being undermined by conspiracy, I beg to explain that Mr. Webster's entire difficulty relating to such alleged conspiracy is the fact that he is unwilling to abide by the basic rule of law applying to all corporations, to-wit: that the majority rule in corporate affairs. An averment of a conspiracy on the part of the vast majority of stockholders of a corporation is usually the product of a most vivid imagination and this is Mr. Webster's principal malady. Mr. Webster will learn that the majority rule in any corporation when the proper times arrives. If the great majority of the capital stock of the corporation desires to pull the organization out of the mire of fourteen years of Mr. Webster's mismanagement, it is an unsafe and illogical conclusion to draw that these stockholders are parties to a conspiracy.

Mr. Webster's position will be defended most advantageously to himself when his several cases come before the courts. I deem it poor policy to use the Press to fight a legal fight, and will therefore refrain from further use of the papers in discussing this matter no matter how libelous Mr. Webster may become. I am,

Very truly yours

H.W. HEFELE

The Lithograph City Enterprise
July 27, 1916, vol. 1, no. 8

The Geology and Life History of the Rocks

The lithological character, and life history of the rock series here, is of deepest interest. The more profound scientific questions involved will be passed until another time, and only the plain and more simple problems dealt with.

The numerous beds of this great rock series varies greatly in many respects, and especially so as to texture and color. There are wonderful problems connected with the coloring of this great book of nature. They vary from black through most of the shades and colors, to a light cream-white, and in texture from medium calcarious granular beds, to those having practically no grain at all. One or more of the beds show very frequent interruptions of fine deposition, which means very much in this ancient and wonderful history. Then in this 100 foot stratum one sometimes sees a bed containing calcarious spar inclusions and occasional small deposits of sulphuretts. Some beds reveal abreciation, showing the once great earth movements and lateral pressure. At one time sedimentation was stopped, the old sea bottom raised to the light of day above the ocean surface, and the sea rolled back as a scroll. Then for a little time there was a new continent here and the soft mud of the sea bottom was baked and cracked deep by the heat of the sun during that old Devonian time. The life of the old ocean then was destroyed and the continent exposed to the sun. Then existed a great yellow mud flat more than one hundred miles in length and of unknown width. This great earth movement was slow and gradual, and then it slowly subsided and the sea rolled over it as before. The climate then was mild and the waters of the sea of very varying depth. A volume might well be written on the wonderful history of this ancient time as revealed by these old rocks.

Along towards the beginning there lived in this ancient sea many small, branching, sponge-like forms that grew in colonies and covered great areas of the old sea bottom. Then life here almost ceased to exist and the sea bottom was almost barren. In the course of ages another series of life forms spread over the region and we find that millions of beautiful shell forms lived and were closely associated together. They now sometimes make up whole layers or beds of rock, which, when sawed and polished, make a beautiful and enduring marble. In the polished slabs today one may read this beautifus history as in a mirror. Then the life forms were changed and almost, if not quite, passed away. Then there occasionally lived an isolated sponge. Then a time was ushered in when the whole great sea bottom presented one great bed of sponges, with many beautiful branching corals, whose cells and inner structure are preserved to us of today. With them also were many shells whose colors must have been bright and beautiful could man but have seen them then. At this time the climate was warm and the sea quiet and shallow. Man was not fore-shadowed then, not even in a prophetic way.

Along toward the beginning too, there swam through the deep the strange and peculiar old armor-clad Devonian fish, unlike anything upon the earth today, or had lived upon the earth until then. And then there lived later one or two species of the old chambered shell, represented by the Nautilus of our present seas. During some of these changing times there lived, practically to the exclusion of all other forms, myriads of shell forms we call Lameliibranchs (a long, hard name) and so numerous were they that they crowded each other for room. Then changes, great changes came, and the wonderful life series perished, the leaves of the old book were turned and a new time and a new life came in. Old nature is ever changing and seems never satisfied with the old and ever striving onward for the newer and better. Running thru the vast story of all of earth's ages is seen the eternal word of change, change, forever change. In all this wonderful and marvelous record we clearly read the mind and thought of Divinity.

Unknown paper, May 8, 1918

SHERIFF'S SALE

Notice is hereby given, that by virtue of a special execution duly issued by the Clerk of the District Court of Floyd County, State of Iowa, and to me directed, I have levied on and shall offer for sale at public auction, at the front door of the Museum building in Devonia, Floyd County, Iowa, on the 31st day of May, A.D. 1918, at 10 o'clock in the forenoon of said day, the following described property, to wit:

Lot number Thirteen (13) in block number Twelve (12) Lithograph City, now called Devonia, in Floyd County, Iowa, and all contents of house located thereon, including experimental laboratory, and all its attachments, furniture, books, etc., lot number number Thirteen (13) in block number Eleven (11) in Lithograph City, now called Devonia, Floyd County, Iowa, and all the contents of the museum building thereon, consisting of specimens of fossils forms, rocks, samples of marble, show cases, boxes containing rocks and specimens of all kinds, and everything contained in said museum and basement thereof, 122 boxes of rocks, and fossils and 26 bundles of like material, 12 boxes of books and envelopes, 18 marble slabs, also Jasper rock on lot number (14), block Four (4) of said Lithograph City, all of the aforesaid property being now situated in the town now known as Devonia formerly Lithograh City, Floyd County, Iowa, levied on as property of Clement L. Webster, to satisfy said Execution in favor of Interstate Investment & Development Company and against Clement L. Webster for $17,267.76 and interests and costs. Terms of sale, cash in hand.

Dated May 1st, A.D. 1918.

C.G. Gray.
Sheriff Floyd County, Iowa.

GEOLOGY AND DISCUSSION OF THE LITHOGRAPH CITY QUARRIES

Brian J. Witzke and Bill J. Bunker
Iowa Department of Natural Resources
Geological Survey Bureau
Iowa City, Iowa 52242-1319

LITHOSTRATIGRAPHIC BACKGROUND

Devonian limestone strata in Floyd and Mitchell counties were studied by a number of geologists over the past century. The geologic observations and interpretations of these studies deserve recognition, especially the early survey by Calvin (1903), the painstakingly careful field studies of Belanski (e.g., 1927), the economic investigations of Clement Webster, the unpublished studies of Nelson (1939) and Stainbrook (1944), and stratigraphic studies by Kohls (1961), Koch (1970), and Mossler (1978), among others.

Up through the 1970s, the Devonian limestone and dolomite bedrock units found below the Shell Rock Formation in the Floyd-Mitchell area were usually included within the "Cedar Valley Formation," and exposed strata were generally assigned to the "Rapid" and "Coralville" members based on general lithologic assumptions. In this usage, "Rapid" strata generally included primarily dolomite, and "Coralville" strata incorporated primarily limestones (commonly "sublithographic"). These member names were originally derived from type localities in Johnson County, Iowa. The use of these names in northern Iowa and southern Minnesota by the respective geologic surveys presupposed that correlations were firmly established with respect to Johnson County. Nevertheless, no regional lithostratigraphic or biostratigraphic studies had actually been undertaken to assess these proposed correlations across Iowa until the 1980s. Nelson (1939) clearly recognized these problems at an early date, and suggested an independent stratigraphic nomenclature for Cedar Valley strata in Floyd County.

Various groundwater investigations in the early 1980s were initiated in the Floyd-Mitchell County area by the Iowa Geological Survey (Floyd-Mitchell Project), and a hydrostratigraphic framework was required to assess the various bedrock aquifers in the region. A preliminary framework was presented by Witzke and Bunker (1984) that indicated that significant miscorrelation of Rapid and Coralville strata in the Floyd-Mitchell area had characterized previous studies, both published and unpublished. Witzke and Bunker (1984) initially opted to subdivide the Cedar Valley strata into a series of informally lettered units (A through E), pending further study. By 1985 a series of bedrock cores that penetrated Devonian strata in the two county area had been drilled by the Iowa Geological Survey, and the informal litho- and hydrostratigraphic framework was more firmly established (Witzke and Bunker, 1985). These cores, used in conjunction with numerous exposures of Cedar Valley strata in northern Iowa, provided the basis for revised correlations of these strata into east-central Iowa (Witzke et al., 1985).

The authors (Witzke and Bunker), along with colleague Jed Day, belabored various options for a formal lithostratigraphic nomenclature of Cedar Valley strata in northern Iowa. Various attempts were made to rectify usage of the long-established east-central Iowa nomenclature with practical considerations in northern Iowa. It was a difficult decision at the time to opt for a state-wide revision of Cedar Valley stratigraphy, but we saw no other alternative. The significant miscorrelations into northern Iowa simply could not be rectified within the existing framework. In addition, several significant natural boundaries had been identified within the interval of Cedar Valley strata that needed to be recognized within the stratigraphic framework (Witzke and Bunker, 1984). In northern Iowa these boundaries were marked by erosional disconformities; they subdivided major transgressive-regressive packages (cycles) of deposition across the region.

The first proposal for a revised formal stratigraphic nomenclature appeared in a Geological Society of Iowa Guidebook by Bunker, Witzke, and Day (1986). They elevated the Cedar Valley to group status (Cedar Valley Group), and proposed a new formation within the group, the Lithograph City Formation, for strata mistakenly correlated with the "Coralville Member" in many previous studies. The type locality was chosen at the old lithograph stone quarries near the site of the now abandoned townsite of Lithograph City. This locality was of interest not only for historic reasons It also adequately characterizes the general lithofacies contained within the formation, including vuggy dolomites, fossiliferous and stromatoporoid-bearing limestones, intraclastic and laminated carbonates, lithographic and sublithographic lime mudstones, and shale. Bunker et al. (1986) further recognized an upper Idlewild Member and a lower Osage Springs Member within the formation, named after nearby localities in Floyd and Mitchell counties, respectively (see Stop 3, this trip). The new stratigraphic nomenclature received wider distribution within the geologic community, and Cedar Valley stratigraphy was further defined and revised, at the International Symposium on the Devonian System in Calgary, Alberta (see Witzke et al., 1988).

THE QUARRIES AT LITHOGRAPH CITY

Visitors at Stop 2 will see the type locality for the Lithograph City Formation, and view evidence of former quarrying activity for lithographic engraving stone (Lithograph City quarrying 1916-1917) as well as later stages of quarrying for aggregate (Dykeman Quarry operations). These quarries are now inactive. Please be cautious along the quarry walls, and be respectful of this interesting and historical private property. We gratefully acknowledge the cooperation and historical information provided by landowner Leroy Jones and his father, Wayne Jones.

A graphic and written desciption of the strata exposed in these quarries is provided. These strata span the middle part of the Lithograph City Formation, which are included within the Idlewild Member (type locality at the large quarry north of Floyd). The general section includes: 1) a lower sparsely fossiliferous dolomite (Units 2-5), probably exposed during later stages of aggregate quarrying activity; 2) alterations of fossiliferous limestone and dense lithographic and sublithographic limestone (units 7-17); and 3) an upper highly calcitic dolomite unit (Unit 18).

The best quality lithographic stone is found in the lower part of the quarry sections (Units 8-10), and a number of small quarries were opened in the vicinity to extract these beds. The lithographic stone is characterized by dense beds, commonly milky white when freshly exposed, that break with a conchoidal (glass-like) fracture. Most of the lithograph stone is remarkably free of impurities, sedimentary structures, and fossils. However, stylolites are scattered, and the beds are very faintly laminated in part. Unit 10 contains wavy and domal laminations, probably algal stromatolites. Petrographically the lithographic stone is a dense pelleted lime mudstone (pelmicrite). The depositional setting of these pure limestone beds is not completely clear, but their general association provides some cludes.

All the lithographic and sublithographic limestone beds in the quarries are found in the upper parts of small-scale sedimentary cycles that range between 0.7 and 3 m in thickness (see Figure). These small cycles (which are termed "punctuated aggradational cycles" by some geologists) were formed by small changes in sea-level (of either local or eustatic origin). A minor deepening of the Devonian seas in the area was marked by expansion of shallow-marine facies at the base of each cycle, which include fossiliferous limestones containing brachiopods (primarily *Allanella*) and crinoid debris with scattered gastropods (snails) and stromatoporoids (sponge-like colonial organisms).

The shallowing phase of each small-scale cycle is marked by deposition of pelleted to laminated lime mudstones and a general absence of marine fossils. These are commonly laminated to stromatolitic, characteristic of shallow lagoonal and mudflat settings. The presence of so-called "birdseye" structures in some of the sublithographic beds (Unit 19) supports deposition in supratidal (subaerially-exposed) mudflat environments. Each small-scale cycle is abruptly overlain by the next marine transgression, whose base is generally slightly irregular and incorporates reworked material from the underlying beds. It is not yet known if these small-scale cycles can consistently correlated across Iowa, but there appears to be a close correspondence between the vertical stacking of similar (and perhaps correlative) cycles at some localities (e.g., compare the Lubben Quarry section described by Bunker et al., 1986, with the Lithograph City quarries). Further study is encouraged.

The proposed itinerary at Stop 2 will include a brief group discussion in a small lithograph stone quarry located between the larger east and west pits. We will see the exposed lithographic layers in the quarry floor, partially removed and stockpiled; quarrying activity must have suddenly ceased at this site, possibly at the time the Interstate Investment Company failed. Late quarrying activity expanded some of the older lithograph stone quarries for aggregate production, including the areas here labeled the east and west pits (see stratigraphic figure). After group discission, trip participants will be encouraged to examine the geology of the additonal quarry areas. See if you can recognize the following rock types and geologic features:

1) Locate the stromatolitic laminations in the upper lithograph stone interval (unit 10). 2) Find the vertical stack of small-scale depositional cycles, each with a lower fossiliferous interval and an upper lithographic or sublithographic interval. 3) Identify the restricted-marine fauna in the fossiliferous beds (*Allanellla* brachiopods, crinoid debris, stromatoporoids). 4) A stockpile of boulders (possibly glacial erratics) in the west pit includes strangely silicified and iron oxide-impregnated Devonian rocks (sub-Cretaceous surface?) as well as iron-cemented pebbly sandstones (derived from the Cretaceous Windrow Formation). Cretaceous rocks overlie Cedar Valley strata at various locations in Floyd and Mitchell counties, primarily isolated remnants of fluvial sandstone and conglomerate (locally with plant fossils including *Tempskya* fern-wood). The Cretaceous rocks record an earlier period of karst and valley-filling sedimentation during the age of dinosaurs.

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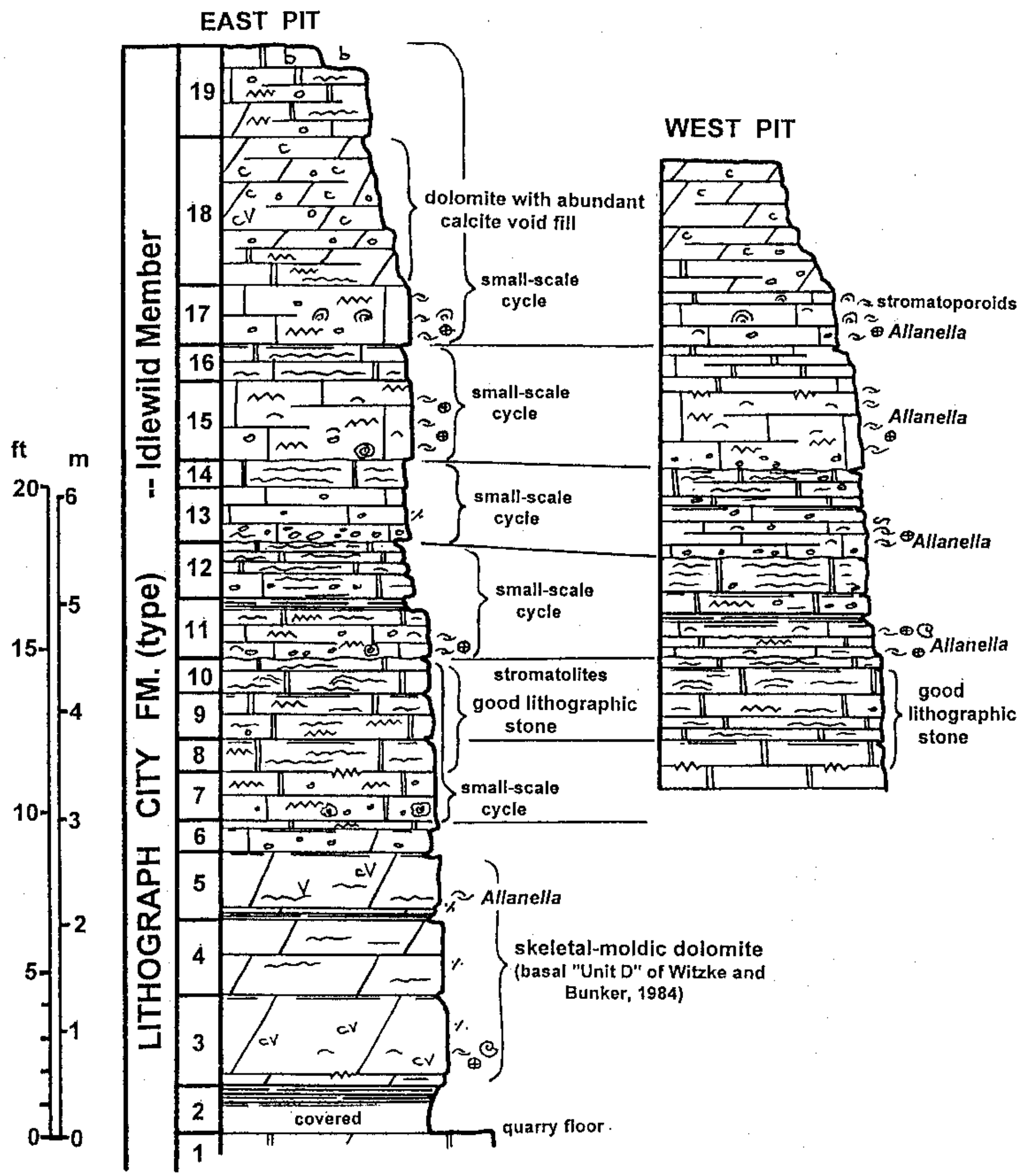

See page 114 for Key.

LITHOGRAPH CITY QUARRIES (former Plynn Dykeman Quarry), Floyd Co., Iowa
Leroy Jones property
Type section of the Lithograph City Formation (Bunker et al., 1986, Witzke et al., 1988)
descriptions based on sections in the East Pit (NE SW NE sec. 26, T97N, R17W) and West Pit (NW SW NE sec. 26); Brian J. Witzke and Bill J. Bunker, March 26, 1985 and Sept. 8, 1995.

LITHOGRAPH CITY FORMATION

IDLEWILD MEMBER

Unit 19. (Seen only in highest parts of the central quarry area, east pit). Limestone, dolomitic in part, ledges at top, stylolitic, most is sublithographic to lithographic, part with irregular laminations, part fractured to intraclastic; "birdseye" fenestrae locally near top; 85 cm noted.

Unit 18. Dolomite, very calcitic, medium bedded, very light yellow-orange, sucrosic very fine to medium crystalline dolomite; fractures and void spaces are filled with calcite spar and domains of poikilotopic calcite, calcite spots common, part vuggy, scattered intraclasts of argillaceous to shaly dolomite to 2 cm diameter; lower 50 to 60 cm is a limestone to dolomitic limestone, very light brown-gray to yellow-brown, part sublithographic and stylolitic, scattered small brachiopods at base; approximately 1.4 to 1.5 m thick.

Unit 17. Limestone, very light brown to brown-gray, massive to medium bedded, skeletal wackestone to packstone, becomes sparsely fossiliferous to sublithographic in upper 11 cm; stylolitic; scattered intraclasts in lower half; scattered to common crinoid debris and brachiopods (including *Allanella*), rare gastropods; middle of unit with scattered hemispherical to massive stromatoporoids (to 12 cm diameter), stromatoporoids become rarer and smaller (to 4 cm diameter) in upper part of unit; indeterminate conodont elements recovered; 50 to 58 cm thick.

Unit 16. Limestone, thin to medium bedded, extremely-finely crystalline to sublithographic, finely laminated throughout; more faintly laminated in lower 10 cm with indeterminate skeletal debris; thin shale parting at top; 35 to 44 cm thick.

Unit 15. Limestone, very light brown-gray, massive ledge-former, base slightly irregular; skeletal wackestone to packstone, common stylolites; lower 20 cm with scattered to common intraclasts (to 1.5 cm); concentrically-laminated subspherical clasts scattered near base (to 5 cm diameter), may be oncolites or stromatoporoids; upper half with common calcite spots and void fills; crinoid debris and brachiopods (including *Allanella*) scattered to common throughout; general upward decrease in size and abundance of skeletal debris; conodonts recovered (*Polygnathus* sp. near base, *Panderinellina insita* in lower half); 72 to 74 cm thick.

Unit 14. Limestone, very light brown-gray, extremely finely crystalline to sublithographic, slightly argillaceous, part finely laminated; thinly interbedded with slightly more argillaceous limestone, part stylolitic; part sublithographic to lithographic laterally, with scattered intraclasts; shale parting (to 2 cm) locally at top; 25 to 35 cm thick.

Unit 13. Limestone, very light brown-gray, intraclastic to skeletal wackestone to packstone; basal 10 to 17 cm with common to abundant flat-pebble intraclasts (to 2 cm long), smaller intraclasts scattered upward, intraclastic to pelletal throughout; skeletal material more common in west pit area, common brachiopods (including *Allanella*), rare crinoid debris; upper part becomes less skeletal, "stromatactis" void fills locally present near top of unit; shale parting at top (to 2 cm); indeterminate conodont elements recovered; 44 to 55 cm thick.

Unit 12. Limestone, pale brown gray, extremely finely crystalline to sublithographic; upper 27 to 32 cm is finely laminated, some wavy laminations in middle, minor intraclasts, weathers flaggy, possible "birdseye" fenestrae near top; lower 18 to 27 cm, slightly argillaceous, intraclastic (clasts 1 to 30 mm), stylolites, some calcite spots, part laminated near top, thin shale parting at top; upper contact slightly irregular; 46 to 54 cm thick.

Unit 11. Limestone, very light to light brown, skeletal wackestone to packstone in lower 20 to 30 cm, slightly argillaceous, stylolitic, locally with intraclasts (to 3 cm) including clasts of lithographic limestone (unit 10 lithologies), common brachiopods (*Allanella*) and crinoid debris, rare gastropods, scattered subspherical oncolites or stromatoporoids (to 3 cm), becomes less fossiliferous upward, slightly irregular base; upper 18 to 27 cm, includes limestone in east pit, very light brown, extremely finely crystalline to sublithographic, capped by shaly argillaceous limestone, irregularly bedded with shale (top 7 to 15 cm shaly); conodonts recovered from lower and middle parts (*Panderinellina insita* and an undescribed *insita*-like platform element); 47 to 55 cm thick.

Unit 10. Limestone, very light brown-gray, sublithographic to lithographic, part more finely crystalline, dense, finely to irregularly laminated, some laminae (lower 22 cm) are wavy and stromatolitic with amplitudes of2 to 3 cm; shale parting locally at top; 33 cm thick.

Unit 9. Limestone, very light to pale brown-gray, thin bedded in lower part, upper 17 to 22 cm is single bed, sublithographic to lithographic, some laminae of more crystalline limestone, minor calcite spots and void fill, fine to coarse faint laminae through most, scattered small intraclasts in places; stylolites common; thin argillaceous parting locally at top; 42 to 44 cm thick.

Unit 8. Limestone, very light brown to brown-gray, sublithographic to lithographic, dense, stylolites; faintly laminated (finely laminated, planar to wavy); in one bed, may weather into one to four beds; shale parting at top; 28 cm thick.

Unit 7. Limestone, very finely crystalline, part sublithographic upward, one to two beds; lower 18 cm is a pelleted or fine skeletal wackestone to packstone, sylolites, contains scattered irregular to subspherical structures 2 to 5 cm diameter (oncolitic or stromatoporoid encrusted), intraclasts at base; upper part is dense, with irregular dark indeterminate mottlings, scattered small intraclasts (5 to 15 mm or less); 45 cm thick.

Unit 6. Limestone, dolomitic in lower portion with fine crystalline calcite fabrics; lower 22 cm with scattered intraclasts (1-10 mm), 2 cm shale at top; upper 8 cm is sublithographic with scattered calcite spots, dense, stylolites, sharp contact at top; 30 cm thick.

Unit 5. Dolomite, very light brown-gray, upper 53 cm is massive single bed, extremely fine to very fine crystalline, contains large calcite-filled vugs, part faintly laminated, becomes calcitic upward and approaches a dolomitic limestone, lower 8 cm with indeterminate skeletal debris molds and rare brachiopods (*Allanella*); base of unit marked by a very argillaceous to shaly dolomite and shale, prominent re-entrant 5 to 6 cm thick, capped by a 7-cm thick slightly argillaceous dolomite with common small (1 mm) elongate molds (possibly fecal or ostracode); entire unit is 65 cm thick.

Unit 4. Dolomite, very light brown-gray, in 2 to 3 beds, extremely fine to very fine crystalline, slightly argillaceous, domains of small-scale porosity (especially in middle part) which appear to be indeterminate skeletal molds; unit is faintly laminated; 70 cm thick.

Unit 3. Dolomite, very slightly calcitic, very light brown gray, extremley fine to very fine crystalline, upper 72 cm is a single massive bed,scattered small calcite-filled voids and vugs; scattered to common skeletal molds including brachiopods (athyrids?), crinoid debris, rare gastropods, numerous brachiopods in band about 20 cm above base of massive unit, indeterminate conodont elements recovered; thin shale parting at top; basal 12 cm in 2 to 3 beds, slightly argillaceous, stylolites; unit has yielded indeterminate conodont elements; entire unit is 84 cm thick.

Unit 2. (Poorly exposed unit). Upper 15 cm is a shale, soft, light green to green-gray, becomes harder shaly dolomite in uper 3 cm; basal 25 cm is covered at base of quarry face, not accessed; entire interval about 40 cm thick.

Unit 1. (Quarry floor in deepest part of east pit area). Limestone, very light brown, extremely finely crystalline to sublithographic, with common fine to coarse calcite crystal inclusions; part slightly argillaceous, stylolites; examined a 15 cm thick piece removed from quarry floor.

LUNCH STOP

HISTORIC OSAGE SPRING

OSAGE SPRING

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Groundwater from Osage Spring has been sampled by GSB staff as part of the hydrogeologic and water-quality investigations in Floyd and Mitchell counties. Samples were collected monthly during 1983 and analyzed for nitrate and coliform bacteria; concentrations of several other parameters were determined less frequently. Nitrate-N concentrations were consistently below 1 mg/L, and coliform bacteria were not present. (Libra et al, 1984). Four samples were analyzed for herbicides, which also were not detected. The lack of surficial contaminants—particularly nitrate-N, caused Libra et al. (1984) to suggest the Spring was discharging groundwater from depth, possibly from the "middle" aquifer (i.e., from below the Chickasaw Shale Member). The spring discharges well above the level of the Cedar River, also suggesting a confined or artesian source.

In 1989, a sample from the spring was analyzed for tritium, the radioactive isotope of hydrogen (^3H). Tritium is formed naturally in the upper atmosphere, and has a half-life of about 12.3 years. Large amounts of tritium were released during the atmospheric testing of nuclear weapons, which began in 1953. Groundwater that originated as precipitation before 1953 would have had, by 1989, a tritium concentration of less than 5 "tritium units" (TU; Freeze and Cherry, 1979). The tritium content of the sample from Osage Spring was 15 +/- 8 TU, indicating the groundwater discharging from the spring contained a significant amount of relatively recent (i.e., post-1953) recharge. Tritium analyses of groundwater from the Devonian aquifers in Floyd and Mitchell counties, collected in the mid-1980's, indicate the "middle' and "lower" aquifers contain pre-1953 groundwater, often with tritium concentrations of less the 1 TU (Libra et al., 1994). Libra (1987) sampled groundwater from 42 private wells completed in the "upper" aquifer in Mitchell County for tritium, nitrate, and dissolved oxygen analysis. Thirty-seven of these samples contained >5 TU. These data suggest Osage Spring discharges groundwater from the "upper" Devonian aquifer.

Given the intensive row-crop agriculture and the susceptibility of the upper aquifer in Mitchell County to contamination, the lack of nitrate-N in the relatively "young" groundwater of Osage Spring may seem anomalous. However, this is not uncommon in the county. Of the 42 "upper" aquifer wells sampled by Libra (1987), 15 produced groundwater with <1 mg/L nitrate-N; ten of these also contained >5 TU tritium, much like the groundwater discharging from Osage Spring. Denitrification, the bacterially-mediated reduction of nitrate to nitrous oxides, may account for the lack of nitrogen in these younger groundwaters. Denitrification occurs under anaerobic conditions, and measurements of dissolved oxygen for the young, nitrate-free groundwaters indicated they were all anaerobic. The remaining twenty-seven wells sampled by Libra (1987) contained nitrate-N concentrations of at least 3 mg/L, dissolved oxygen concentrations in excess of 2 mg/L, and had tritium contents of 5 TU or more. Therefore, while groundwater similar to that from Osage Spring is produced by wells completed in the "upper" aquifer, groundwater from the aquifer is more typically "young", aerobic, and contains inputs of nitrate-N from surficial sources.

While dissolved oxygen was not analyzed at Osage Spring, there are indications that anaerobic conditions occur. The water contains dissolved iron and hydrogen sulfide gas, which are generally immobile species in aerobic settings. It is likely the lack of nitrate at Osage Spring—a rather uncommon occurrence for springs in the corn belt—is the result of denitrification.

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BEDROCK GEOLOGY IN THE AREA OF OSAGE SPRING PARK

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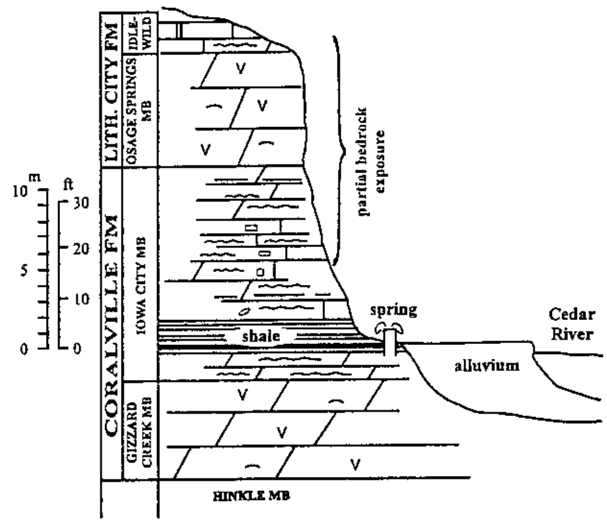
Our lunch stop is on a terrace in the valley of the Cedar River. The river valley in this area is largely walled by exposures of Devonian bedrock of the Cedar Valley Group. Nearly continuous bedrock exposure is seen in the valley walls stretching all the way from Mitchell downstream to Floyd. The bedrock outcrop throughout this stretch of the river is characterized by strata of the upper Coralville Formation (Iowa City Member) in the lower valley walls, and by units of the Lithograph City Formation in the upper valley walls. Where the bedrock is best exposed in the steepest parts of the valley, a prominent cliff-forming unit of thick-bedded vuggy dolomite is particularly distinctive. This dolomite interval, which forms the lower part of the Lithograph City Formation, was named the Osage Springs Member by Bunker et al. (1986) and Witzke et al. (1988).

Although the type locality for the Osage Springs Member is located about 2 miles downstream from Osage Spring County Park (see next Stop), the park is centrally located within a region displaying extensive natural bluffs and cliffs of these strata and is a good name-bearer for the unit. Although better exposures can be found both upstream and downstream from the park, discontinuous outcrop within the park can serve to give a general picture of the bedrock geology in the area (see Figure). Although this stop is primarily designed to be a lunch break, we will lead a short hike along the north valley wall in the park for those interested. The best bedrock exposure in the park is seen along the east trail (N 1/2 SW sec. 27, T98N, R17W).

The lower valley slope in this area shows discontinuous bedrock exposure, blocks, and colluvium derived from the Iowa City Member. These are characterized by restricted-marine and peritidal limestone and dolomite facies, including laminated, intraclastic, and brecciated units. A shale



interval, 1 to 2 m in thickness, is recognized in the lower part of the member throughout the area (see Figure), but this shale unit is rarely exposed and is typically represented by covered and overgrown slopes along the Cedar River valley. Although not exposed in the park, this shale unit is predicted to occur at about the level of the Cedar River. This is of particular note with respect to the springs developed along the terrace margin within the park. The shale unit likely serves as a local confining interval within the "upper" Cedar Valley aquifer (see hydrostratigraphy of Witzke and Bunker, 1984). Where the valley wall cuts across the shale, the effective seal is removed and the confined aquifer is allowed to discharge (see Figure).

The upper bluffs display ledges and colluvium (also transported onto the lower slopes) of blocky dolomite characteristic of the Osage Springs Member. The vuggy blocks contain scattered fossil molds. The highest rocks preserved (minor ledges and blocks of colluvium) include sublithographic limestones derived from the lower part of the Idlewild Member.

STOP 3

THE OSAGE SPRINGS MEMBER, LITHOGRAPH CITY FORMATION

TYPE SECTION OF OSAGE SPRINGS MEMBER

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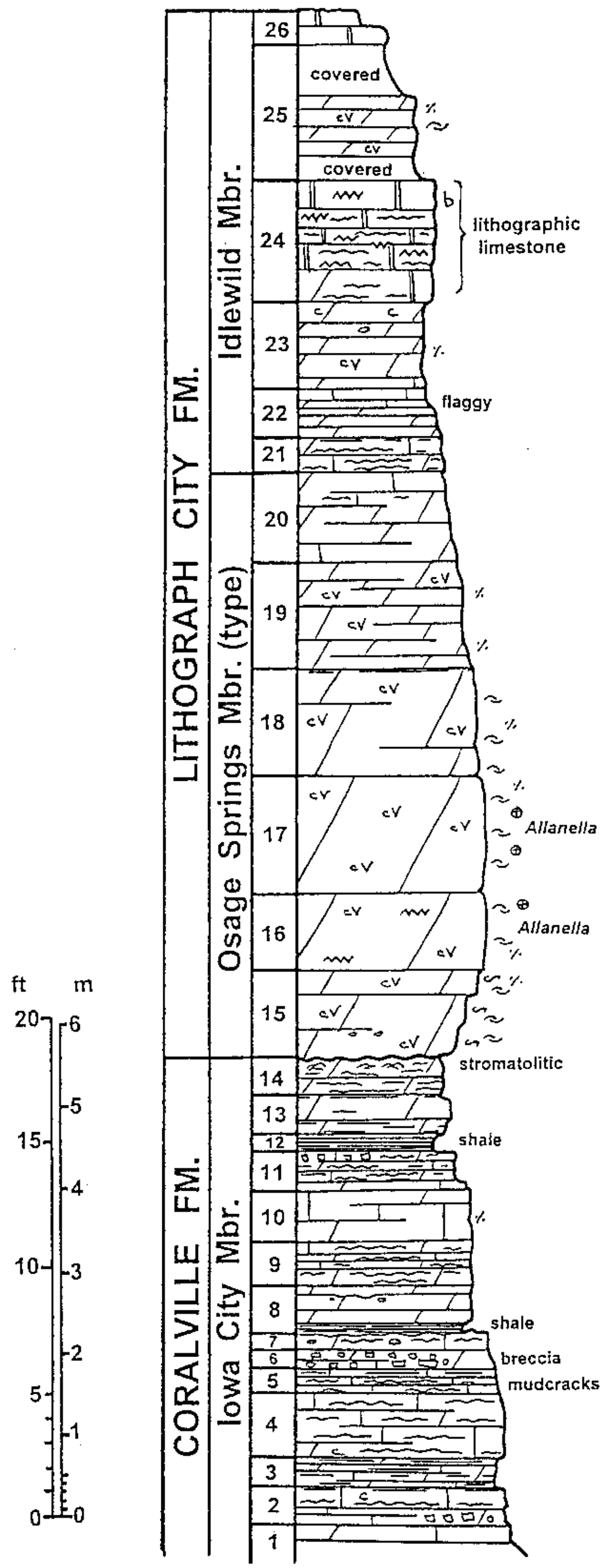
The roadcut and bluff section exposed north of the Cedar River bridge about a mile and a half south of Osage was designated the type locality for the Osage Springs Member of the Lithograph City Formation (Bunker et al., 1986; Witzke et al., 1988). The bold cliff-forming dolomite beds of the Osage Springs Member are dramatically displayed here. These dolomites are typically vuggy, and scattered to common molds of brachiopods (*Allanella*) are seen in some beds. The vugs are commonly lined with calcite crystals. Basal strata abruptly overlie an irregular surface, marking regional transgression of shallow-marine environments and the initiation of a new cycle of deposition.

Underlying strata of the upper Coralville Formation are well displayed in the lower portions of the roadcut and bluff section. These beds are dominated by laminated dolomite and dolomitic limestone. These were likely deposited in restricted shallow settings and mudflat environments. Minor brecciation may relate to dissolution of evaporites (gypsum), as equivalent strata in the subsurface of central Iowa contain extensive evaporite beds. Mudcracks (unit 5) indicate periodic subaerial exposure and desiccation across the mudflat environments. Shale beds occur in strata of the Iowa City Member in northern Iowa (e.g. units 8, 12), but shales are typically absent in the member to the south. The top of the Coralville Formation is marked by an irregular disconformity surface. This surface formed during a regional erosional episode that separated deposition of the Coralville and Lithograph City T-R (transgressive-regressive) cycles.

Strata of the lower Idlewild Member can be seen in the northern portions of the roadcut. An interval of birdseye-bearing lithographic limestone (unit 24) is similar to strata seen at Stop 2, but occupies a slightly lower stratigraphic position. Although the precise correlation of this roadcut section and the historic Lithograph City quarries has not been established, brachiopod-bearing upper beds at the roadcut (unit 25) resemble the basal dolomite interval at Lithograph City and may conceivably correlate. Regardless, lower Idlewild strata include small-scale cycles of sparsely skeletal dolomite capped by lithographic and sublithographic limestone units. Higher in the Idlewild sequence (most of the section at Lithograph City) the small-scale cycles are less dolomitic and include fossiliferous limestone.

This is a potentially dangerous stop. Please be cautious along the highway. The shoulders are narrow and drop precipitously into deep ditches adjacent to the main roadcut exposure. Access can be tricky. Please be careful along the steep rock faces, and be mindful of people below. Unit descriptions will help in your examination of the exposed strata.



See page 114 for Key.

ROADCUT SECTION SOUTH OF OSAGE, Mitchell Co., Iowa

North of Cedar River Bridge along County Road T38 (stretching between bridge and 340th St.)

Type section of the Osage Springs Member (Bunker et al., 1986; Witzke et al., 1988)

descriptions based on measured sections by Brian J. Witzke and Bill J. Bunker, July 14, 1983 and Sept. 8, 1995; units 1 through 17 immediately north of bridge on east side of road (NE NE NE NE sec. 2, T97N, R17W); units 17 through 24 on west side of road (SE SE SE SE sec. 35, T98N, R17W); units 24 through 26 on east side of road south of 340th St (NW SW NW SW sec. 36, T98N, R17W).

LITHOGRAPH CITY FORMATION

IDLEWILD MEMBER

Unit 26. Limestone, ledges, sublithographic, part slightly dolomitic; about 40 cm thick. Unit capped by rocky colluvium with blocks of vuggy dolomite and sublithographic limestone.

Unit 25. Limestone, dolomitic, light yellow-brown, grades upward into dolomite, very fine crystalline, calcite-filled vugs; dolomite with small skeletal molds including small indeterminate brachiopods; basal 30 cm and upper 60 cm is a mostly covered slope; total interval 1.6 m thick.

Unit 24. Limestone, very light brown to pale buff, in ledges 20 to 40 cm thick, most is sublithographic to lithographic; lower half contains scattered to common calcite spots, part dolomitic; stylolitic, most of interval is faintly and finely laminated; top 10 to 20 cm is nonlaminated with possible "birdseye" fenestrae; 1.5 m thick.

Unit 23. Dolomite and calcitic dolomite, very light brown-gray to buff, in ledges 10 to 35 cm; basal 14 cm is a dense dolomitic limestone, very fine to medium crystalline; remainder is dolomite, calcitic, very fine crystalline, with scattered calcite-filled vugs, pin-point porosity development, possible skeletal molds, part with calcite spots; 1.04 m thick.

Unit 22. Dolomite and dolomitic limestone, very light gray to brown-buff, very fine to fine crystalline, thin-bedded to flaggy; 57 cm thick.

Unit 21. Limestone, dolomitic, dense, very fine crystalline, faintly laminated especially in lower part; shale parting at top; 41 cm thick.

OSAGE SPRINGS MEMBER (type section)

Unit 20. Dolomite, slightly calcitic, to dolomitic limestone, buff, bedded 1 to 30 cm, dense, very fine to medium crystalline; part faintly laminated 25 cm from top; shale parting at top; 1.1 m thick.

Unit 19. Dolomite, buff, bedded 10 to 30 cm, abundant calcite void and fracture fill, generally dense, possible fine skeletal debris molds; 1.25 m thick.

Unit 18. Dolomite, buff, massive to irregularly bedded, abundant calcite void and vug fill; molds of brachiopods and indeterminate fossil debris; thin shale parting at top; 1.3 m thick.

Unit 17. Dolomite, buff, massive to irregularly bedded, partly vuggy, abundant calcite void fill, large calcite vug fills to 30 cm diameter; scattered to abundant skeletal debris molds including brachiopods and crinoid debris; 1.45 m thick.

Unit 16. Dolomite, buff, massive, prominent calcite void and vug fills to 15 cm diameter, scattered stylolites, common brachiopod molds (including *Allanella*) and scattered crinoid debris molds; sample yielded conodonts (*Panderinellina insita*); 90 cm thick.

Unit 15. Dolomite, buff, part slightly calcitic, massive to irregularly bedded, calcite void and vug fills common (to 15 cm diameter near top); common to abundant skeletal debris molds including brachiopods; burrow mottling through, horizontal to subhorizontal burrows; irregular base, scattered small intraclasts (to 1 to 2 cm) in lower 30 cm; 1.08 m thick.

CORALVILLE FORMATION
IOWA CITY MEMBER

Unit 14. Dolomite, buff, slightly calcitic, faintly to prominently laminated, lower part with stromatolitic laminations (displays 1 cm amplitude), stromatolitic top 4 cm; top surface is irregular, part truncated, up to 8 cm vertical relief; 46 cm thick.

Unit 13. Dolomite, light brown to buff, very fine crystalline, bedded 1 to 5 cm in lower 15 cm, more massive above; lower part is argillaceous, argillaceous stringer 15 cm above base; 1 cm shale parting at top; 48 cm thick.

Unit 12. Shale, light gray to green-gray, noncalcareous, recessive interval; 22 cm thick.

Unit 11. Limestone, dolomitic, very light to light brown, medium brown to light gray in upper part, thinly bedded; middle part argillaceous to shaly (approaches shale), faintly laminated; top 11 cm is laminated to brecciated, breccia clasts 1 mm to cm, individual laminae show vertical fractures (mudcracks?); 46 cm thick.

Unit 10. Limestone, dolomitic, very light brown, very fine to medium crystalline, massive to irregularly bedded, hard dense, possible indeterminate skeletal debris; 65 cm thick.

Unit 9. Dolomite to dolomitic limestone (upward), light brown, thinly bedded faintly laminiated, alternating laminae of very fine and medium crystalline laminae in lower 22 cm; 52 cm thick.

Unit 8. Dolomite, slightly calcitic, very light green gray with yellow-orange mottlings, possible skeletal debris molds; irregularly distributed microbreccia 11 cm from top, surface truncated laterally with up to 4 cm relief; basal 12 cm is an argillaceous limestone to calcitic shale, green-gray; 57 cm thick.

Unit 7. Limestone, dolomitic, pale brown-gray; lower 7 cm is argillaceous, very fine to medium crystalline; upper 13 cm is laminaed, individual laminae are fractured, rip-up clasts to 2 cm; undulatory upper surface; 20 cm thick.

Unit 6. Limestone, dolomitic, very light yellow orange; argillaceous; brecciated lower 10 cm , argillaceous clasts (1 mm to 3 cm); upper 13 cm is microbrecciated (clasts < 3 mm); 23 cm thick.

Unit 5. Limestone, very light brown, very fine crystalline, thinly bedded to laminated; polygonal mudcracks (10 to 40 cm spacing), thin shale parting at top; 30 cm thick.

Unit 4. Limestone, dolomitic, very light brown, massive, very fine crystalline, faintly laminated, scattered calcite spar void fill; small-scale fault displacement (6 cm) noted on outcrop; 80 cm thick.

Unit 3. Limestone, dolomitic, very light brown, faintly laminated to thinly bedded; becomes argillaceous upward, shaly in top 6 cm; 35 cm thick.

Unit 2. Limestone, very light brown-gray, very fine crystalline, part thinly bedded, faintly laminated 24 to 33 cm above base; lower 24 cm grades laterally into a fine crystalline dolomite breccia, clasts up to 20 cm long; top part includes calcite spar fill; thin shale parting at top; 50 cm thick.

Unit 1. Limestone, dolomitic, light brown-gray, dense, fine crystalline; 16 cm accessed at base of rock exposure above river; 16 cm accessed, covered below.

STOP 4

KARSTIFICATION NEAR FLOYD, IOWA

FLOYD COUNTY GROUNDWATER PROTECTION PROJECT SINKHOLE CLEANOUT

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The Floyd County Groundwater Protection Project was a five year project (1991-1995) whose primary goal was to improve and protect the groundwater resources of the county. The project was funded with EPA Section 319 and REAP-Water Protection Funds. The Natural Resources Conservation Service (NRCS), EPA, DNR, ISU Extension Service, and the Iowa Department of Agriculture and Land Stewardship-Division of Soil Conservation were the participating agencies.

The primary routes of potential groundwater contamination were ADWs, incipient and open sinkholes, and losing streams (streams discharging water to the underlying bedrock). Major sources of contamination included fertilizers, pesticides, manure, and septic effluent. The project developed plans with participating farmers to adopt Best Management Practices (BMPs) to reduce the risk of contamination. Many of these BMPs also were profitable to farmers who utilized these in their operations.

Practices used in the project included sinkhole tile alternate outlets, band spraying, late spring nitrogen test, Integrated Crop Management (ICM), ADW alternate outlets, sinkhole buffer zones, manure management, soil testing, tissue testing, and economic analysis.

The Project employed a full-time coordinator who was located in the NRCS office in Charles City. The project has concluded but is currently wrapping up some details including the final report. A follow-up project called the Tri-County Water Quality Project is scheduled to start in the fall of 1996 in Floyd, Butler, and Mitchell counties.

From 1992-1994, the Iowa Department of Agriculture and Land Stewardship conducted a sinkhole cleanout program in eleven northeast Iowa counties. Sinkholes on private lands that were used as public open dumps were eligible to be cleaned at no cost to the owner. Figure 1 is a map of Floyd County that shows the locations of known sinkholes and ADWs.

Contracts were let to private contractors under a competitive bidding process to remove debris, haul it to landfills, and recycle tires and scrap metal. The landowner was required to establish and maintain seeding and to prevent future dumping.

Stop 4 of this field trip was cleaned in 1993 a cost of $16,428. Debris removed from the sinkhole included 91 tires, asphalt shingles, metal cans, plastic jugs, pesticide containers, household trash, appliances, fence wire, and sheet metal.

The totals for Floyd County and the state of Iowa were:

Year	Iowa	No.	Floyd County	No. Cleaned
1992	$414,089.16	36	$80,891	7
1993	$182,603.30	29	$41,207	6
1994	$56,833.17	13	$6,607	2
TOTAL	$653,525.63	78	$128,705	15

STOP 5

A LOOK AT PLEISTOCENE ICE WEDGES

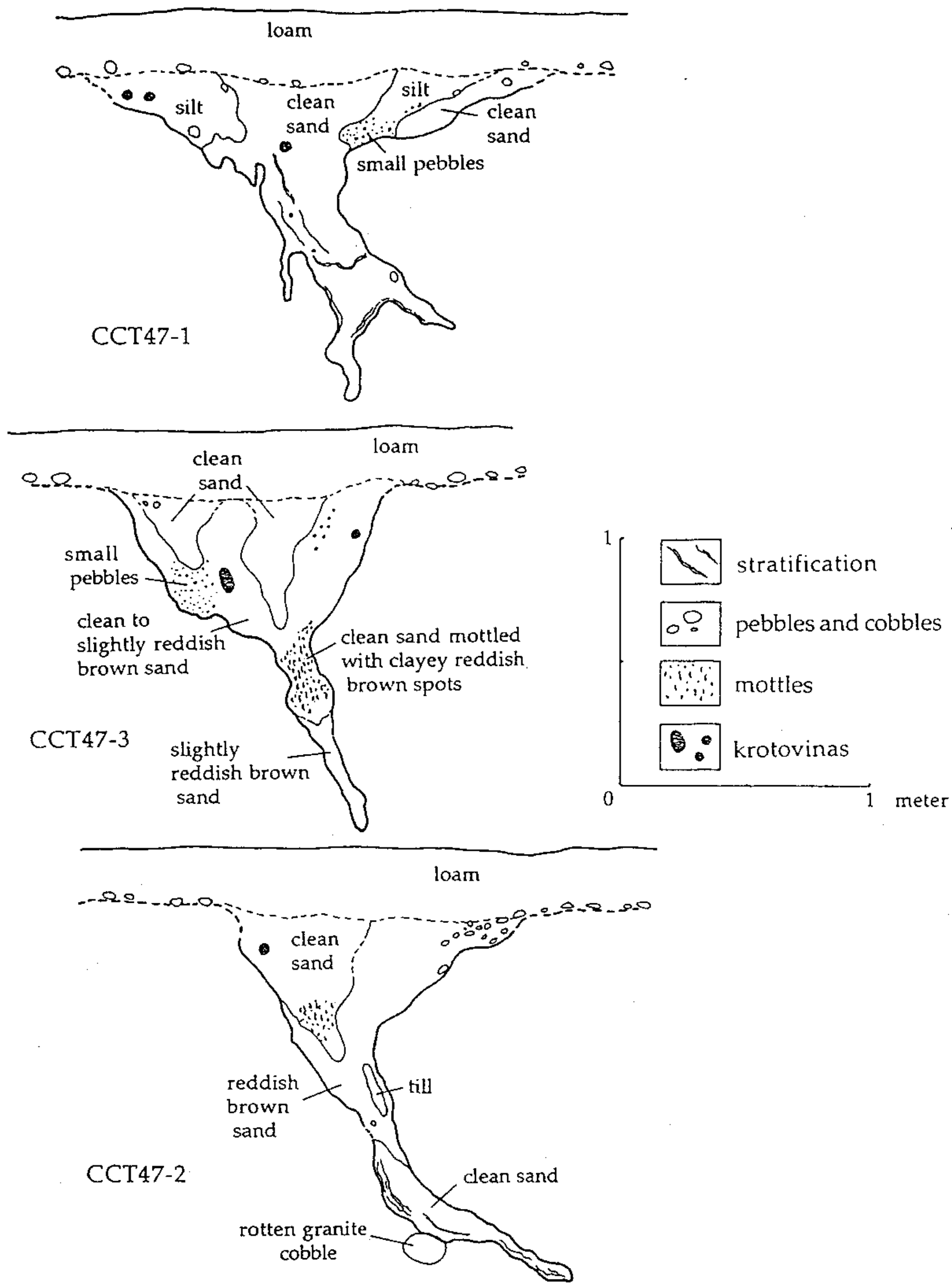

Figure 1. Cross-sectional sketches of wedges at drainage ditch site along county road T47, approximately 7 km west of Charles City, Iowa. Drawn from field observations and photographs. All wedges occur in pre-Illinoian age till.

SEDIMENT-FILLED WEDGES SITE WEST OF CHARLES CITY

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INTRODUCTION

In the fall of 1994, in conjunction with a project on agricultural drainage wells in the vicinity, the ditch on the west side of county road T47 approximately 7 km southwest of Charles City, was widened and deepened. Deb Quade and Lynette Seigley of the Iowa Geological Survey Bureau, in examining the excavation, noted what appeared to be wedge-shaped fillings of sand in the till. Later visits to the site in the summer of 1995 confirmed the existence of numerous sediment-filled wedges of sand. Characteristics of these features suggest they are ice-wedge casts. I present here a brief report on the wedges at this site, their possible mode of origin, and paleoclimatic implications.

WEDGE CHARACTERISTICS

Sediment-filled wedges are exposed on both the east-facing and west-facing side of the north-south drainage ditch. The ditch is separated into a northern and southern component by a culvert over which a farm driveway connects with the paved road. Although wedges probably exist on both sides of the culvert, they are only exposed on the north side. This is due to the fact that the north side is deeper (approximately 3 m) and less disturbed than the south side. On the north side of the culvert, the ditch is approximately 140 m long and 6 m wide at the top. Although I studied only five wedges in detail, there are at least 25 wedges exposed in the ditch (total of both east-facing and west-facing exposures).

Cross sections of three of the wedges investigated are shown in Figure 1. All wedges are in pre-Illinoian till and are oriented vertically or near vertically and taper downward into a round point or points. Wedges range in width across their tops from 0.5 m to over 2.5 m but average width is about 1.2 m. Wedge depth is difficult to measure due to the 25° to 30° slope of the excavation, but average depth appears to be approximately 1.5 m. The material filling the wedges is mostly quartz sand which is fine to medium-grained but ranges from very fine to very coarse-grained. Most of the sand infilling is clean and loose, but in places the sand is reddish brown due to iron staining. Pockets of silt and sandy silt and stringers of silt and clay also occur in places in the wedges. Stratification of the infilling material is evident in some of the wedges and is usually more or less parallel to the wall of the wedge. In addition, small gravels and pebbles are sometimes found within the sand, and there are occasional inclusions of till host material found in the wedge infilling.

Overlying the wedges is about 35 to 50 cm of sandy loam with a stone line at its base. Occasional ventifacts are found in the stone line. The stone line descends several centimeters into the upper portions of the wedges. As mentioned earlier, the host material in which the wedges occur is a pre-Illinoian till, but investigations reveal that there are actually two such tills at this site. The wedges normally penetrate only the upper, yellowish reddish brown till. A gray, clayey paleosol is developed into the lower till. In a few places, the normal sequence of sediment-filled wedge in upper pre-Illinoian till overlying the paleosol of the lower pre-Illinoian till is totally confused. In these situations, sand from a wedge filling can be found within both upper and lower tills as pockets, lenses, and irregularly-shaped masses, with upper and lower tills also contorted and intermixed.

The wedges appear to describe a polygonal pattern in plan view as observed by the lateral continuity of wedges on both sides of the drainage ditch and the spacing between adjacent wedges.

Spacing between wedges was measured in an attempt to ascertain the approximate size of the polygonal cells. Because of the nature of the excavation at this site (i.e., no vertical exposures and no scraped surface showing a plan view), only a rough approximation of 6 to 10 m can be given.

WEDGE ORIGIN

Wedge-shaped features can form in sediments for a number of reasons (Black, 1976); however, because the wedges at this site show a polygonal pattern, it is necessary only to consider those processes producing such a pattern. These are desiccation cracking, tensional fracturing, and thermal contraction cracking. Of these three possible modes of origin, only thermal contraction cracking, which produces secondary wedge structures, fits with the characteristics of the sediment-filled wedges at this site. Several comprehensive reviews exist which describe important characteristics present in such features (Péwé and others, 1969; Black, 1969, 1976; Romanovskij, 1976; Harry and Gozdzik, 1988). The presence of slump features, pockets of silt and sand, occasional small gravels and pebbles, and inclusions of adjacent and overlying material in the wedge filling all suggest that these wedges formed as sediment replaced a melting ice wedge. Sediment was probably washed, blown, and slumped into the degrading ice wedge. Wedge infilling preceded the development of the stone line and overlying loamy sediments, but some ice must have persisted in the lower portions of many wedges as indicated by the descent of the stone line into the upper part of most wedges.

PALEOCLIMATIC IMPLICATIONS

Sediment-filled wedges are common on the Iowan Erosion Surface of northeast Iowa, although few descriptions of them exist (Walters, 1994). They have characteristics which suggest they are ice-wedge casts and formed in a former periglacial environment with permafrost. Ice-wedge casts have also been reported from northeast Nebraska (Wayne, 1991), central Illinois (Johnson, 1990), southwest Wisconsin (Black, 1969, 1976), and southeast Minnesota (Hobbs, 1991). Based on the available information, Wayne and Guthrie (1993) developed a map showing permafrost-related periglacial features between central Indiana and the Rocky Mountain front and the probable southern limit of discontinuous permafrost. Their map includes all of northeastern Iowa within the zone of permafrost. Studies of fossil pollen, plant macrofossils, small mammals, insects, and molluscs at sites in Iowa and adjacent states indicate that this region had an arctic climate with open tundra conditions between 21,000 and 16,500 years BP, the coldest part of late Wisconsinan time (Baker and others, 1991). The ice-wedge polygons in northeast Iowa likely formed at this time.

The presence of disturbed or contorted sediments in some sections of the exposure at this site is suggestive of involutions produced by freeze-thaw processes and soft-sediment deformation during the degradation of ice-rich permafrost. Since the disruption also includes wedge fillings, it means that this activity took place after the ice-wedge casts had formed or at least toward the end of their formation.

Degradation of the permafrost and conversion of the ice wedges to ice-wedge casts took place as the climate began to moderate some time around approximately 16,500 years ago. An erosion surface had been forming in northeast Iowa during much of the period of intense cold as freeze-thaw activity, solifluction, overland flow, and wind erosion caused extreme downwearing of the upland landscape (Bettis and Kemmis, 1992). Now known as the Iowa Erosion Surface, this landscape continued to develop even as the ice wedges were transformed into ice-wedge casts. This is evident because of the nature of the stone line as it crosses the tops of the wedges and descends into their upper portions. Loamy sediments accumulated toward the end of this period of extreme downwearing, burying the erosion surface and the ice-wedge casts. The ice-wedge casts are observable today in temporary exposures as sediment-filled wedges.

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STOP 6

ABANDONED AGRICULTURAL DRAINAGE WELLS

MONITORING OF A PIEZOMETER NEST AND NEARBY PRIVATE WELLS IN AN ADW CLOSURE AREA, FLOYD COUNTY, IOWA

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INTRODUCTION

Previous investigations in Iowa have identified areas where surficially-derived contaminants, particularly nitrates and commonly used pesticides, have caused degradation of groundwater in regionally extensive bedrock aquifers (Hallberg and Hoyer, 1982; Hallberg et al., 1983, 1984, 1989; Libra et al., 1984, 1991, 1994). These studies have shown that the depth to the bedrock aquifers and the presence or absence of karst features have a major influence on the potential for surficial contaminants to reach groundwater. Geologic regions based on these criteria were delineated in Floyd and Mitchell counties. In Floyd County and adjacent areas, where Devonian system carbonate strata form a widely used multi-aquifer system, stratigraphic relationships influence the extent and degree of groundwater contamination (Witzke and Bunker, 1984; Libra et al., 1984). In addition, areas with significant numbers of agricultural drainage wells (ADWs) are present in parts of Floyd and other counties in northern Iowa. The ADWs have been shown to deliver tile-drainage water and surface waters containing nitrates, pesticides, and microbial contaminants to groundwater (Musterman et al., 1981; Baker and Austin, 1984, Libra et al., 1994). In 1994, a project was initiated to monitor the effect closure of several ADWs in a small area in Floyd County would have on the water quality of the Devonian aquifer system. This project was designed to monitor and document groundwater quality improvements resulting from the closure of three agricultural drainage wells (ADWs) in central Floyd County. These ADWs discharge nonpoint source pollutants, from agricultural tile drainage and some runoff, into the three-part (upper, middle and lower) Devonian carbonate aquifer system. Two of the closed ADWs were approximately 65 feet deep and injected water into the upper Devonian aquifer while the third ADW was over 300 feet deep and injected water into all three of the aquifers. As of late December 1994, these three ADWs were closed and their tile drainage diverted to a constructed drainage ditch. This afforded an opportunity to monitor the effects of three ADW closures on the Devonian aquifer system: one deep (>300 feet) ADW as well as two shallower ADWs. In this part of Floyd County, the Devonian aquifers are covered with over 50 feet of low permeability materials and past investigations have shown that groundwaters in such areas are naturally protected from agricultural contaminants (Hallberg and Hoyer, 1982; Hallberg et al., 1983, 1984, 1989; Libra et al., 1984, 1991, 1994).

In 1984 a piezometer nest (Site FM3), completed within the Devonian aquifers, was installed within 500 feet of the deepest ADW (ADW-1) proposed for closure; all three ADWs are within a one-half mile radius of the piezometer nest. Groundwater quality at the FM3 nest and drainage to ADW-1 has been monitored since 1984. Groundwater quality of tile drainage to the two 65 feet deep ADWs (KRUM-ADW and SARR-ADW) has been monitored during 1994. No background groundwater quality information is available for two nearby ADWs (D & L and Toebe) recently closed in the summer of 1995. Monitoring has shown that ADWs are delivering agricultural contaminants to the groundwater of this otherwise "protected" area. The water quality from the FM3 piezometer nest is responsive to the inputs from these ADWs.

The Floyd County Soil and Water Conservation District (SWCD), with the approval of the Iowa Department of Agriculture and Land Stewardship (IDALS), has closed these ADWs and diverted their drainage to an alternate outlet that discharges to nearby Beaver Creek.

The IDNR-Geological Survey Bureau (IDNR-GSB) has monitored water quality during the pre-closure and immediate post-closure period that has formed the first year of this project (1994). The IDNR-GSB will continue monitoring the FM3 piezometer nest and nearby private wells during the next two years to document expected changes in the groundwater quality of the Devonian aquifers resulting from the ADW closures. These results should be applicable to ADW closures in other areas of the state. The quality of the diverted drainage will also be monitored to assess impacts on the receiving stream and address possible concerns for downstream leakage of the diverted drainage from Beaver Creek to the underlying groundwater system.

HYDROLOGIC SETTING OF FLOYD COUNTY

The hydrogeology and water quality of the Devonian aquifers in Floyd and Mitchell counties were discussed by Libra and others (1984, 1994), and are briefly reviewed here. Figure 1 is a map of the geologic regions of Floyd and Mitchell counties. Libra and others (1984) added an additional area, termed incipient karst, to Hallberg and Hoyer's (1982) three original regions. The incipient karst is characterized by a very thin (<20 feet) cover of Quaternary material over the carbonate aquifers, and the presence of numerous shallow, closed depressions interpreted as "incipient" sinkholes. These areas occupy broad, low-relief, upland positions and are marked by high rates of infiltration. Using the geologic regions defined in Hallberg and Hoyer (1982), the incipient karst areas would be shallow bedrock areas, and therefore are considered susceptible to surficial contamination. Most of Floyd and Mitchell counties are shallow bedrock or incipient karst regions. The most extensive deep bedrock area occurs along the eastern part of the area. This area marks the location of a bedrock channel, now filled primarily with low permeability glacial till. Depth to the bedrock aquifer exceeds 300 feet in this area. Another large deep bedrock area occurs in central Floyd County, on the upland divide between the Cedar and Shell Rock rivers.

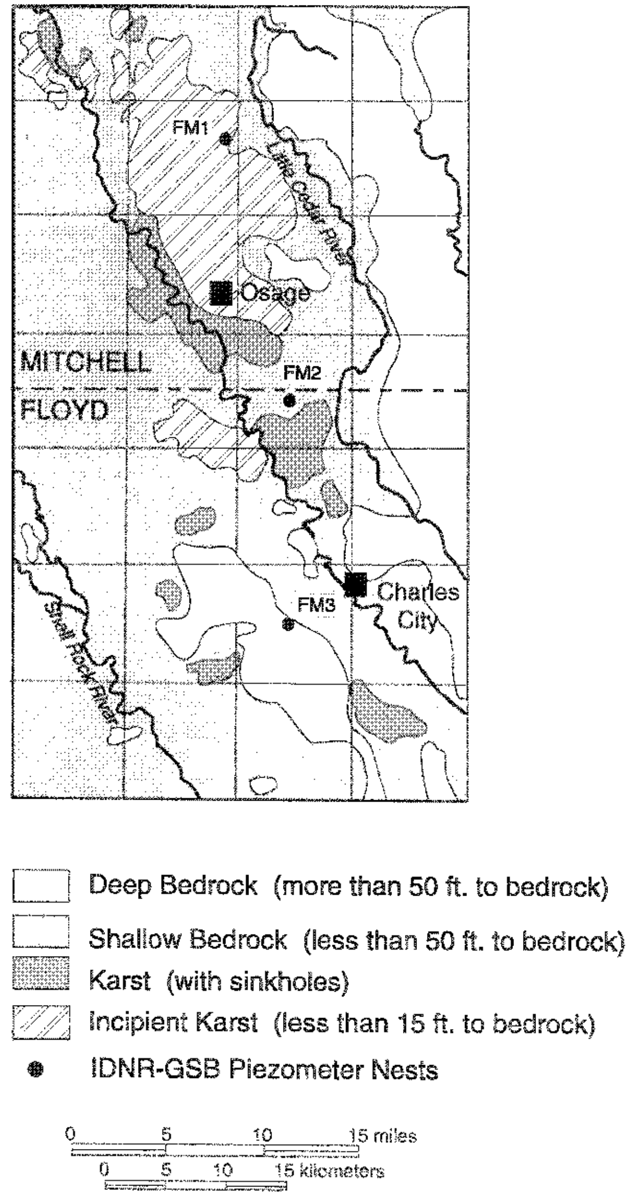


Figure 1. Map showing geologic regions for Floyd and Mitchell Counties (modified from Libra et al., 1984).

Stratigraphic and hydrogeologic studies (Witzke

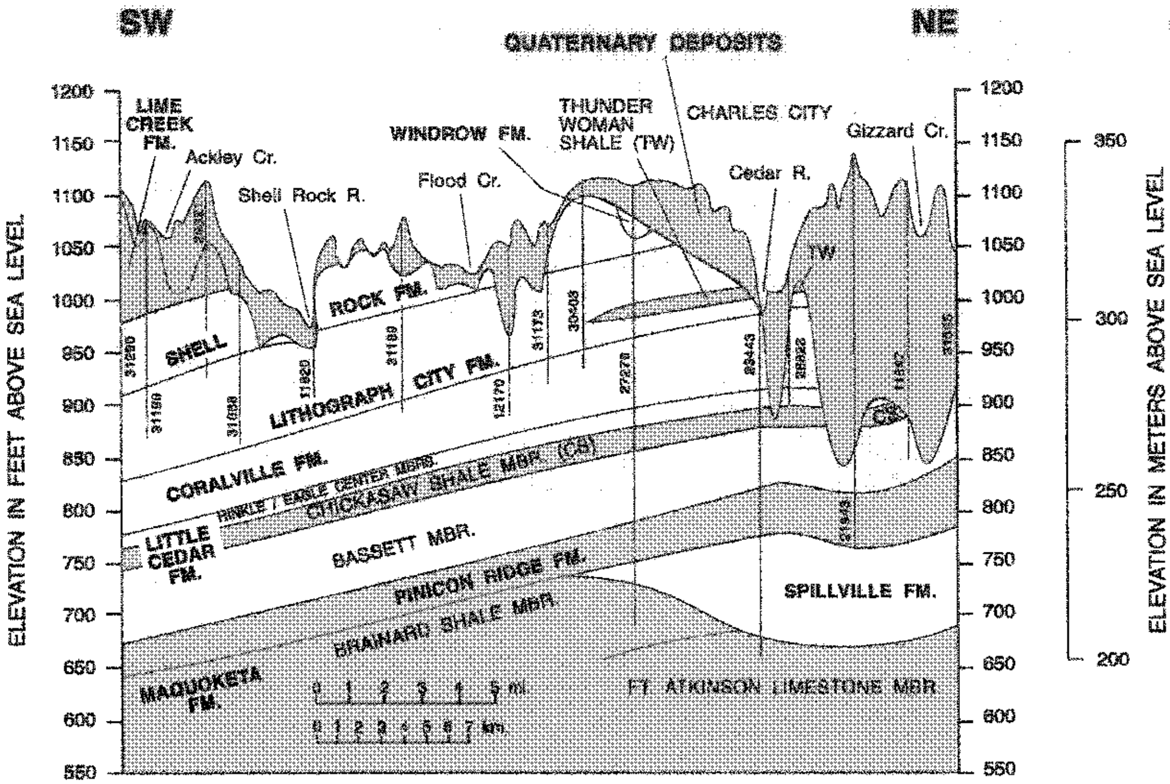


Figure 2. Geologic cross-section of the Devonian system in Floyd and adjacent counties (from Libra and Hallberg, 1993).

and Bunker, 1984; Witzke et al, 1988; Libra et al., 1984) suggest the Devonian strata in Floyd-Mitchell counties are best described as a three-part aquifer system with the major water-producing carbonate strata separated by intervening shales and shaley carbonates. Figure 2 is an east-west cross-section of the Devonian strata. Three major aquifers are noted on Figure 2, and these are informally termed the "lower," "middle," and "upper" aquifers for purposes of this report. The Spillville Formation forms the lower aquifer, and the Bassett Member of the Little Cedar Formation acts as the middle aquifer. The upper aquifer consists of the Hinkle and Eagle Center Members of the Little Cedar Formation, and the Coralville, Lithograph City, and Shell Rock Formations. Major confining beds include the Chickasaw Shale Member of the Little Cedar Formation and the Pinicon Ridge Formation. These confining units are believed to be fairly extensive in north-central Iowa (Witzke and Bunker, 1985). Limited water quality sampling of wells completed below the Chickasaw Shale generally showed no detectable nitrates or pesticides (Libra et al., 1984). General trends shown by the potentiometric mapping indicate regional flow from upland positions to the large streams and rivers, which act as discharge zones. Existing vertical head data in upland areas and in major river valleys, though limited, support this conclusion (Munter, 1980; Libra et al., 1984).

Climate Data

Precipitation records illustrate the variability in precipitation in Floyd and Mitchell counties during the study period. The mean annual precipitation is 32.76 inches for the Charles City station and is based on the record from 1951 to 1980.

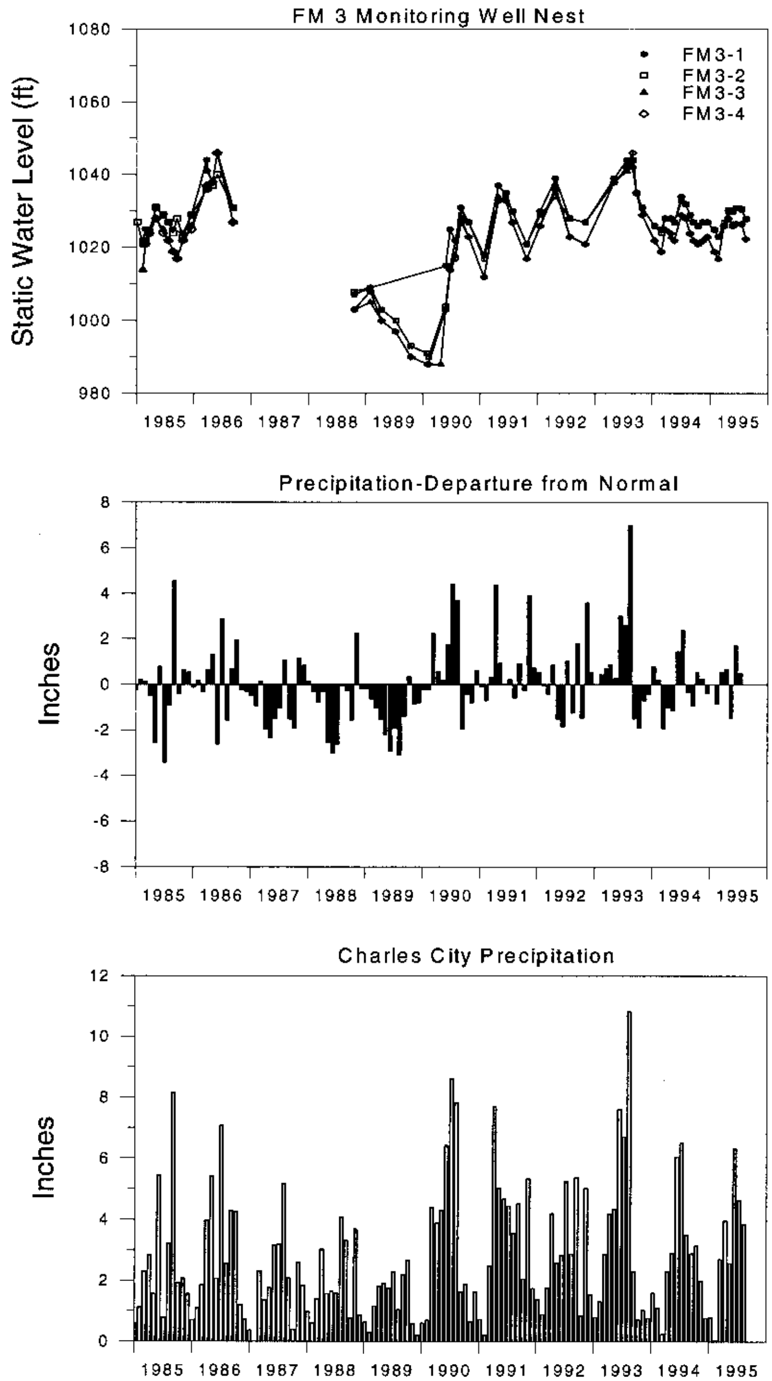


Figure 3. Static water levels from a nest of four research wells in the Devonian aquiifer in Floyd County, departure from normal precipation and precipitation at Charles City, Iowa.

Figure 3 illustrates the effects of these climatic variations on groundwater recharge at the FM3 piezometer nest located in central Floyd County. The three graphs show water levels, precipitation, and departure from normal precipitation from January 1985 through early 1995.

Water levels at the FM3 monitoring well nest reflect longer-term temporal variations in precipitation patterns in Floyd and Mitchell counties. In 1986 this area experienced above normal precipitation followed by the worst drought recorded in Iowa's history from 1988 to 1989. By late summer of 1990, water levels had responded to above normal precipitation and returned to levels comparable to the mid 1980s. Also, precipitation patterns have continued a trend of above to slightly above normal from 1990 through the fall of 1993.

Longer-term monitoring of hydrologic systems in Iowa (e.g., Floyd-Mitchell, Big Spring Basin, and the Bluegrass Watershed projects) agree that the frequency of pesticide detections and the concentration of nitrates were lower during the drought interval than in previous or subsequent years (Kross et al., 1990; Rex et al., 1993). These previous investigations suggest a relationship between the temporal variability of atrazine and other farm chemical concentrations in groundwater with precipitation patterns. A primary factor to consider in water-quality studies is the temporal relationship between climate and the variability of chemical concentrations in various hydrologic systems.

WATERSHED AREA

The proposed study area is in central Floyd County, an area with a concentration of ADWs in a deep bedrock aquifer setting. Previous studies by the IDNR-GSB have described the hydrogeology of the area and documented the water quality impacts of the ADWs. The general geologic setting of the area is fractured Devonian carbonate bedrock which is overlain with >50 feet of low permeability, Cretaceous rocks and Pre-Illinoian glacial till. Soils in the watershed are the Readlyn-Tripoli association. These soils form in nearly level to gently sloping terrain, are somewhat poorly drained to poorly drained, and formed in loamy sediments and the underlying glacial till. This soil association is intensively rowcropped with a corn and soybean rotation. This is a unique setting because the IDNR-GSB has collected groundwater quality data from the FM3 bedrock monitoring wells completed in the Devonian aquifer system since 1984. Monitoring data from this site has documented the occurrence of nitrates and pesticides in all three of the Devonian aquifers at this site. Also, IDNR-GSB has monitored tile effluent injected into the deep ADW (>300 feet) described. This ADW is within 500 feet of the piezometer nest and its adverse impact on the Devonian aquifer system is clearly measurable, as it discharges water into all three of the aquifers at this site.

WATER QUALITY PROBLEM

The Devonian aquifers are important regional sources of groundwater for drinking water and other uses throughout eastern Iowa; it is estimated that they supply water to over 90% of the private wells in Floyd County, in addition to many municipal sources. Numerous ADWs of varying depth are injecting tile-line effluent and surface water into the underlying Devonian aquifers, delivering agricultural nonpoint source contaminants into the aquifer; notably nitrate, pesticides, sediment, and possibly animal wastes. Within the upper Devonian aquifer, this problem is most discernable in deep bedrock areas (>50 feet of surficial cover over bedrock) where such contamination is not a common occurrence. However, water quality samples from piezometers have documented the occurrence of nitrate and pesticides intermittently above health advisory recommendations. Closure of the ADWs will provide a basis for direct comparison and documentation of water quality changes.

To eliminate the nonpoint source groundwater contamination from these ADWs, the Floyd County SWCD proposed closing the deep ADW at this site as well as two nearby ADWs that are approximately 65 feet deep. These three ADWs are the closest ADWs to the piezometer nest; the nest and all three ADWs occur within a one-half mile radius. The ADW closure and eventual diversion

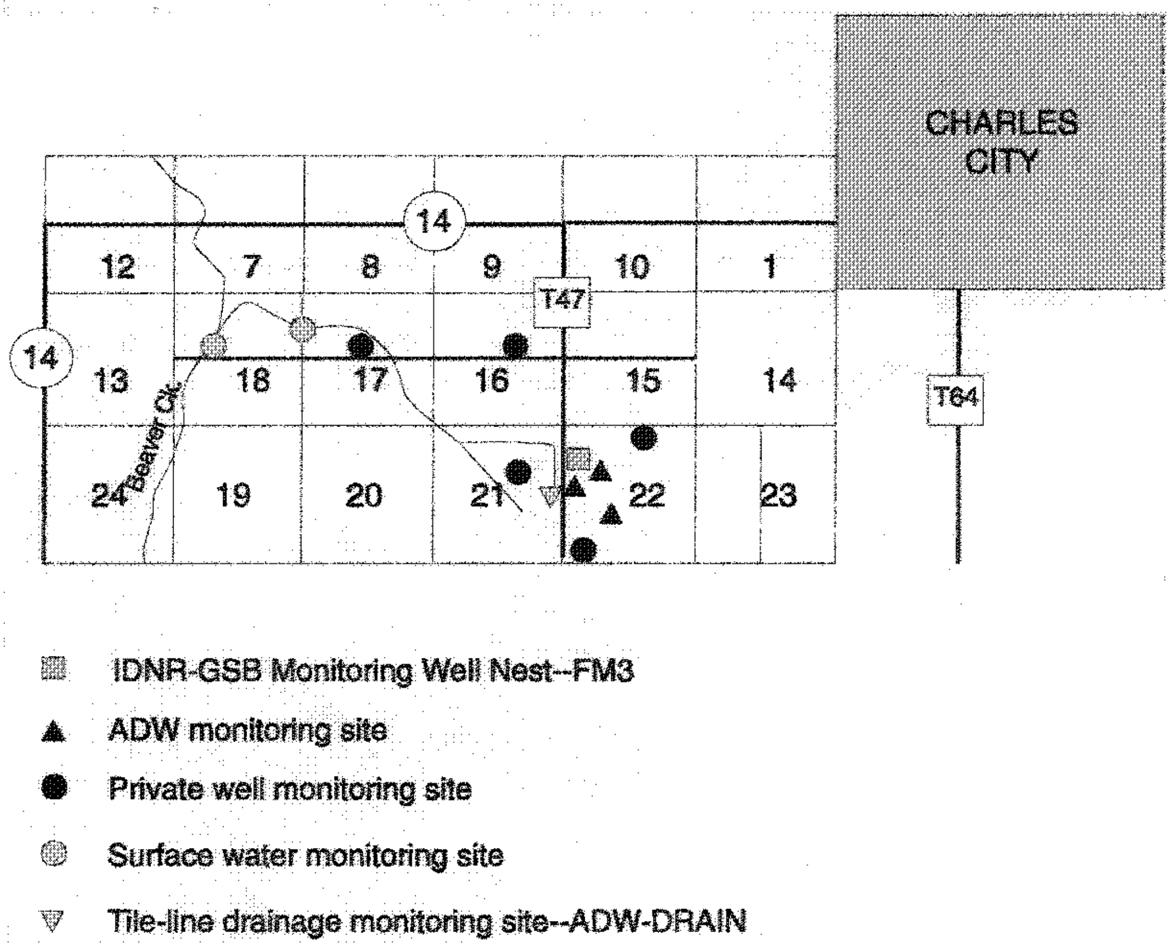


Figure 4. Location map of ADW Closure Project monitoring sites and closed ADWs.

will affect 280 acres of land and will involve three landowners who have agreed to cooperate with closure. Figure 4 shows the location of the five ADWs, the IDNR-GSB piezometer nest, Beaver Creek, and the route of the alternative drainage outlet.

Monitoring Plan Design

This project will monitor water quality at nine sites. Monitoring sites include the FM3 piezometer nest, the tile-line drainage from the three closed ADWs, two downstream surface water sites on Beaver Creek, and five private wells that are within a one-mile radius of five recently closed ADWs (Fig. 4). The FM3 monitoring well nest consists of four bedrock wells and one glacial till well. The FM3 site is within 500 feet of one of the closed ADWs and has a long-term monitoring record. The ADWs referred to as the SAR-ADW, KRUM-ADW, and ADW-1 were closed in mid-December 1994 and tile drainage from those ADWs now drains into a drainage ditch referred to as ADW-DRAIN. The ADW-DRAIN eventually drains into a tributary of Beaver Creek; surface water sampling points are located at a bridge site on the tributary (TRIB-UP) and at another bridge site immediately downstream on Beaver Creek (BC-DOWN). The selection of these various sites allows for the monitoring of groundwater, shallow groundwater, and surface water during this project.

WATER QUALITY PARAMETERS

Water-quality samples will be analyzed by the University Hygienic Laboratory (UHL) in Iowa City, an EPA certified laboratory. Information on analytical methods is given in Table 1. Table 1 is a list of the chemical parameters analyzed. The lab routinely runs internal calibration standards for the listed pesticides, as well as other spikes, duplicates, and blanks for quality assurance and quality control. Hallberg and others (1990) provide a more detailed review of the methods.

The method of analysis for total coliform bacteria is the Most Probable Number (MPN) method, based on the Standard Methods for Water and Wastewater Method 908A (APHA, 1985). Results are statistically derived from the estimated number of total coliform bacteria organisms in 100 milliliters of water, rather than a direct count. There are six MPN numbers reported: 0, 2.2, 5.1, 9.2, 16 and >16. The 0 indicates no total coliform bacteria were present, and is reported as safe while the range from 2.2 to >16 MPN indicates positive detections of total coliform bacteria. Drinking water should be free from coliform bacteria. The presence of coliform bacteria indicates the potential for disease-carrying bacteria to enter the drinking water supplies. Nitrate results, reported as NO3-N are in milligrams/liter (mg/L); one mg/L is equal to one part per million (ppm). The drinking water standard for nitrate, as set by U.S. EPA, is 10 mg/L. Nitrate-N was analyzed by copper-cadmium reduction and colorimetric quantitation using a Technicon auto-analyzer system, and included nitrate plus nitrite-N. Analyses below the quantitation limit for nitrate were reported as <0.10 mg/L. For statistical analysis, values below the quantitation limit were given a value of 0.05 mg/L.

Currently eight herbicides plus two atrazine metabolites are included in the multi-residue analysis by UHL. The pesticides were analyzed by gas chromatography (after U.S. EPA, 1980) with dual-flame photometric and/or nitrogen-phosphorous detectors. The quantitation limit (the smallest concentration that can confidently be reported by the lab) for the analyzed herbicides was 0.1 micrograms (μg/L), which is one tenth of a part per billion (ppb). All detections were confirmed and quantified on two columns with periodic confirmation with electron-capture detectors and GC-mass spectrometry. For statistical analysis, values below the quantitation limit were given a value of 0.05 μg/L.

WATER-QUALITY MONITORING

The IDNR-GSB has conducted numerous groundwater quality investigations in Floyd and Mitchell counties during the last decade. Several studies focused on the hydrologic setting and the effects of ADWs on groundwater quality and on the delivery of shallow groundwater (i.e., tile drainage water) and some surface runoff water into underlying aquifers (Libra and Hallberg, 1993 and Libra et al., 1994). Past studies have documented the concentration of ADWs in central Floyd County and delineated this area as a region with >50 feet of surficial cover over bedrock. This area, like similarly delineated areas in Floyd and Mitchell counties, is considered to be "protected" and should have low nitrate concentrations (1 mg/L NO_3-N) and infrequent or no detections of pesticides in groundwater. Water quality data from a nested piezometer site and tile-line (ADW-1), southwest of Charles City have documented the impact of ADWs on the Devonian aquifer system. The results from the monitoring of bedrock piezometers (groundwater), and shallow groundwater

Table 1. Summary of chemical parameters analyzed as part of studies conducted in Floyd and Mitchell counties; samples, laboratory, methods, and holding time requirements. (See Hallberg et al., 1990, Kross et al., 1990, and Hall and Moyer, 1990, for details of methods).

Analyte Name	Other Name	Method	MDL / method detection limit	Sample holding time	Extract holding time
Bacteria:					
total coliform		MTF - Multiple	<2.2("0") to >16 Probable Number statistical function	48 hours	N/A
Nitrate:					
nitrate		Cu-Cd reduction	<1.0 mg/L	48 hours	N/A
Herbicides:					
alachlor	Lasso	GC-FP/NPD	0.10 µg/L	7 days	40 days
atrazine	Atrazine	GC-FP/NPD	0.10 µg/L	7 days	40 days
butylate	Sutan	GC-FP/NPD	0.10 µg/L	7 days	40 days
cyanazine	Bladex	GC-FP/NPD	0.10 µg/L	7 days	40 days
metolachlor	Dual	GC-FP/NPD	0.10 µg/L	7 days	40 days
metribuzin	Sencor	GC-FP/NPD	0.10 µg/L	7 days	40 days
trifluralin	Treflan	GC-FP/NPD	0.10 µg/L	7 days	40 days
acetochlor	Harness Plus	GC-FP/NPD	0.10 µg/L	7 days	40 days
metabolites:					
de ethyl atrazine		GC-FP/NPD	0.10 µg/L	7 days	40 days
de isopropyl atrazine		GC-FP/NPD	0.10 µg/L	7 days	40 days

(ADWs and till piezometer) will be briefly discussed in the following sections. Figure 5 illustrates a vertical section of the three-part Devonian aquifer and depths of piezometers at IDNR-GSB's FM3 monitoring well nest. This piezometer site was sampled on a monthly basis from November 1984 through May 1986. Monthly monitoring resumed in January 1990 and will continue at this site for the duration of this project. Impacts from nearby ADWs are most evident in FM3-1, the shallow bedrock piezometer and in FM3-4, the deepest bedrock piezometer.

The water-quality results from long-term monitoring of the FM3 piezometer site and nearby tile-lines (ADWs) are presented in this section. The water-quality data are summarized by concentration or occurrence of certain analytes and the percentage of wells affected. For statistical analysis, 0.05 mg/L values were assigned for nitrate-N observations below the method detection limit and 0.05 µg/L (half the detection limit value), for pesticide observations below the method detection limit. This section will discuss long-term monitoring from shallow groundwater sites (three tile-lines and one till piezometer) and from groundwater (four bedrock wells). As mentioned previously, these different hydrologic settings influence the occurrence and extent of agricultural contaminants in groundwater.

Nitrate

Shallow Groundwater

Nitrate concentrations are reported in milligrams per liter of nitrate-N (mg/L NO_3 -N). The natural background nitrate concentration in groundwater aquifers of Floyd and Mitchell counties is less than 1 mg/L NO_3-N (Hallberg and Hoyer, 1982; Libra et al., 1984). Shallow groundwater samples were obtained from three tile lines (ADW-1, KRUM-ADW, and SARR ADW) and from the till piezometer, FM3-T. Tile line samples are representative of water quality at the top of the water table, while the till piezometer sample is characteristic of water within the glacial till at depths between 10 and 25 feet below the land surface. ADW (tile-line) and till-piezometer locations are given on Figure 4. Nitrate data from shallow groundwater sites are given on Table 2. Data from tile line ADW-1 are samples collected from a large main tile that discharges into an ADW located about 500 feet south of Site FM3. Data from the tile line KRUM-ADW are samples collected from a main tile that discharges into an ADW located about 1,500 feet east of Site FM3. Data from the tile line SARR-ADW are samples collected from a main tile that discharges into an ADW located about 3,000 feet southeast of Site FM3. Typically, tile lines do not run in very dry periods, indicating the water table had dropped below typical tile depth of 4 to 6 feet. During such periods there is little or no delivery of infiltrating recharge to the water table, or to ADWs. Similar conditions also exist during the coldest parts of the year when frozen soil conditions and precipitation falling as snow do not allow recharge to occur. During periods when the tiles were discharging, nitrate median concentrations at the three ADWs varied between 8 and 28 mg/L NO_3-N; samples from ADW-1 had significantly lower nitrate concentrations than the KRUM-ADW and SARR-ADW sites (Table 2) . At ADW-1, the highest pesticide concentrations occurred in samples collected during major recharge periods (Fig. 6). During times when significant recharge occurs, nitrate is mobilized and carried by infiltrating recharge water down to the water table. Previous studies (Hallberg et al., 1983; 1984; Libra et al., 1984) have documented a general increase in nitrate and pesticide concentrations in shallow groundwater during such recharge periods, with lower concentrations occurring during drier periods (i.e., drought conditions of 1988 and 1989). This trend is apparent in the data from long-term monitoring at ADW-1. Shorter term monitoring of

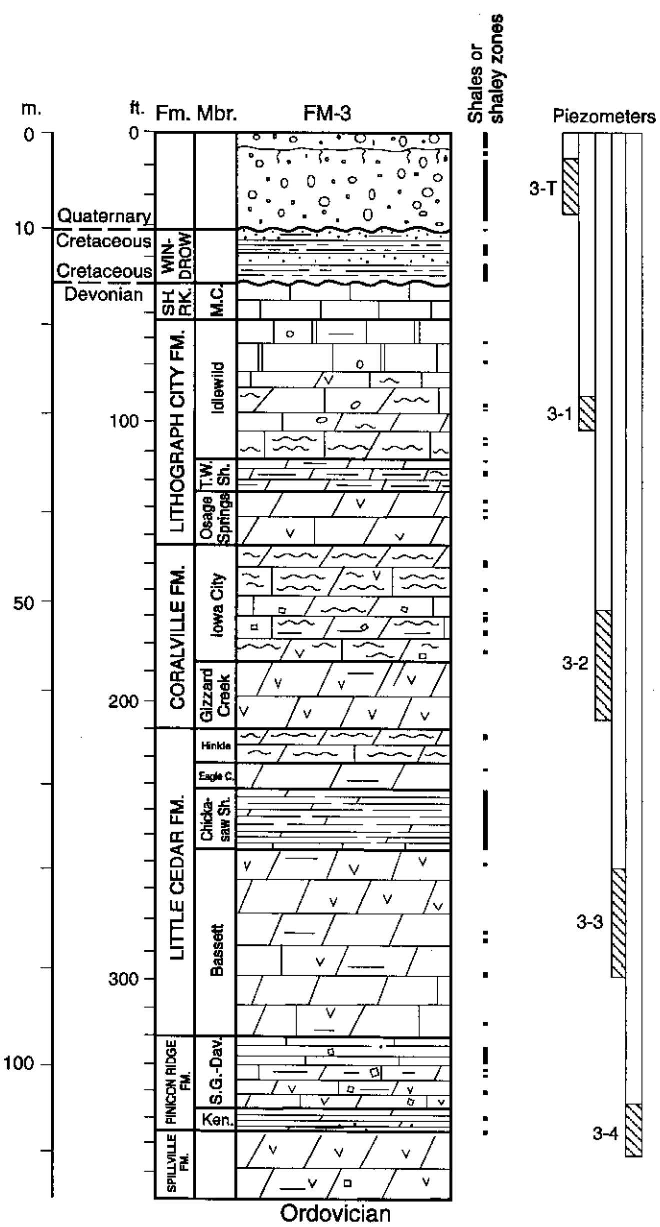


Figure 5. Geologic log, and piezometer completions, Site FM3 (from Libra et al., 1994).

SARR-ADW and KRUM-ADW documents the decrease in nitrate and pesticide concentrations in August and September 1994, related to drier conditions (Figures 7 and 8).

Nitrate concentrations are relatively low at the till piezometer site, FM3-T; the median nitrate-N concentration is 3.2 mg/L (Table 2). A factor that

Table 2. Water-quality results from shallow groundwater—tile lines and till piezometer.

Water-Quality Parameter	FM3-T	ADW-1	KRUM-ADW	SARR-ADW
Number of samples:	45	33	11	11
Nitrate-N:				
number (%) sites >10 mg/L (HAL)	8 (18%)	11(33%)	9 (82%)	10 (91%)
mean conc., mg/L	5.0	9.6	23.7	20.0
median conc., mg/L	3.2	8.3	28	20.44
max conc., mg/L	22	24	34	35
% of wells with nitrate-N >10 mg/L				
--- with an atrazine detection	0 (0%)	5 (16%)	8 (80%)	9 (90%)
Number of samples:	36	32	10	10
Atrazine Detection:				
number (%) sites with detections	12 (33%)	18 (56%)	8 (80%)	10 (100%)
mean conc. of detections, µg/L	0.16	0.38	0.46	0.81
median conc., µg/L	0.15	0.2	0.46	0.76
max conc., µg/L	0.3	2	0.6	1.1
Any Pesticide Detection:				
number (%) sites with detections	13 (36%)	22 (69%)	8 (80%)	10 (100%)
Multiple Pesticide Detections:				
number (%) of sites with 2 or more detections	9 (25%)	14 (44%)	8 (80%)	10 (100%)

may account for the low nitrate concentrations is the presence of a paleosol at Site FM3. A paleosol often contains a horizon with a relatively high clay content. This clay-rich horizon may act as a low permeability barrier, limiting downward groundwater movement. FM3-T is constructed such that the open interval extends below the paleosol. Therefore, FM3-T may be in a locally "protected" zone, where groundwater tends to move laterally, with slow downward movement across the paleosol. Long-term monitoring at FM3-T documents similar trends in nitrate concentrations that are related to climatic variability (Fig. 9)

Bedrock Piezometers

The piezometer sites have been sampled during the same sample periods as the sites previously discussed. Figures 10 through 13 examine the relationship between nitrate-N and potentiometric data. Site FM3 piezometers indicate a general seasonal occurrence of high heads and higher nitrate-N concentrations. This occurs particularly in the upper aquifer, monitored by the two uppermost bedrock piezometers (FM3-1 and FM3-2), where the impact of nitrate-rich recharge water is volumetrically more important. Nitrate concentrations at Site FM3 (greater than 50 feet to bedrock) vary widely. Table 3 summarizes water quality statistics from bedrock piezometers. Nitrate-N concentrations vary from maximum concentrations of 54 mg/L in the upper aquifer (FM3-1) to 0.5 mg/L in the middle aquifer (FM 3-3) to 8.5 mg/L in the lower aquifer (FM3-4). During relatively dry periods, the uppermost piezometer, FM3-1, generally produced water with less than 10 mg/L

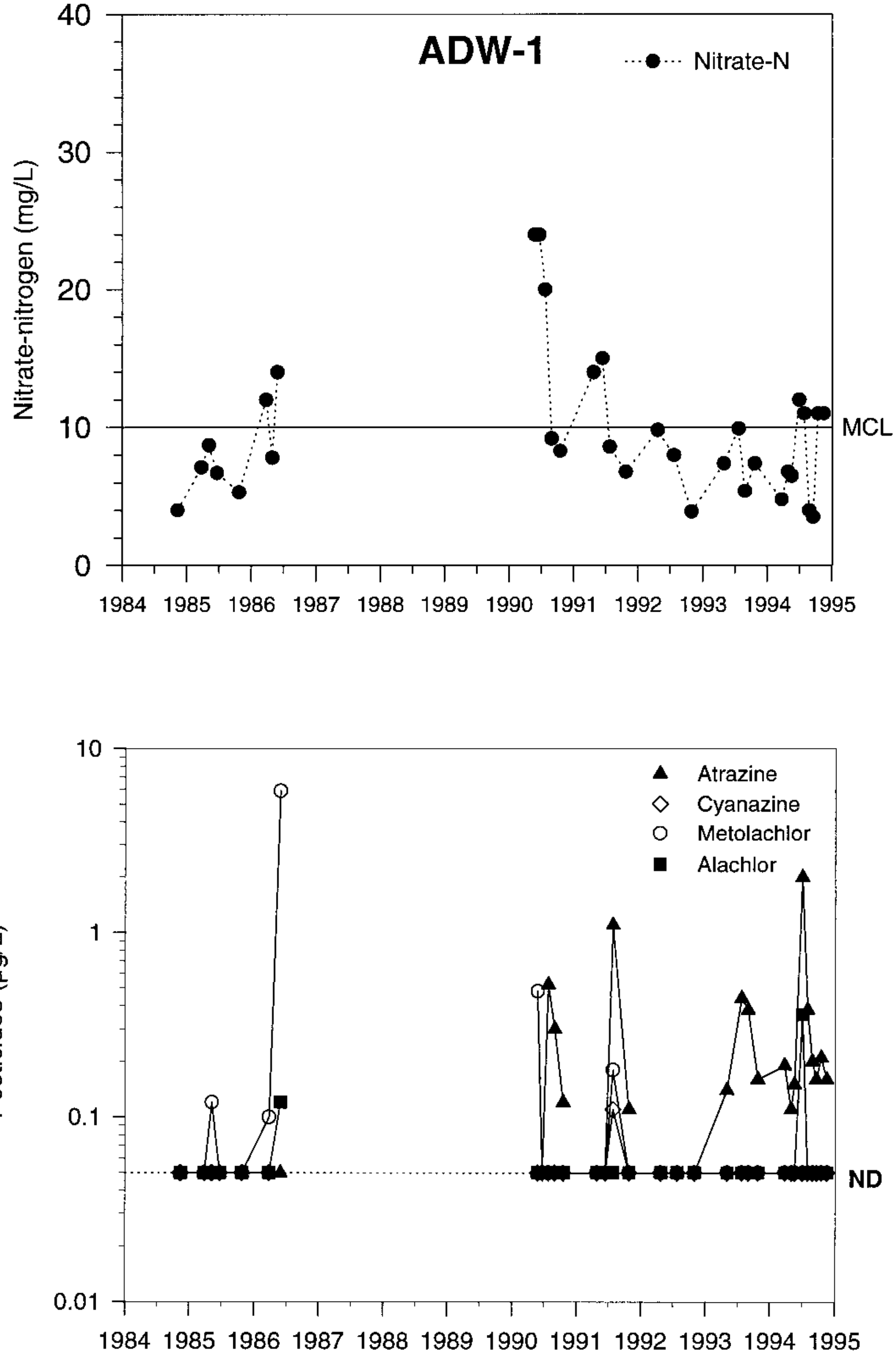


Figure 6. Nitrate-nitrogen and pesticide concentrations at ADW-1.

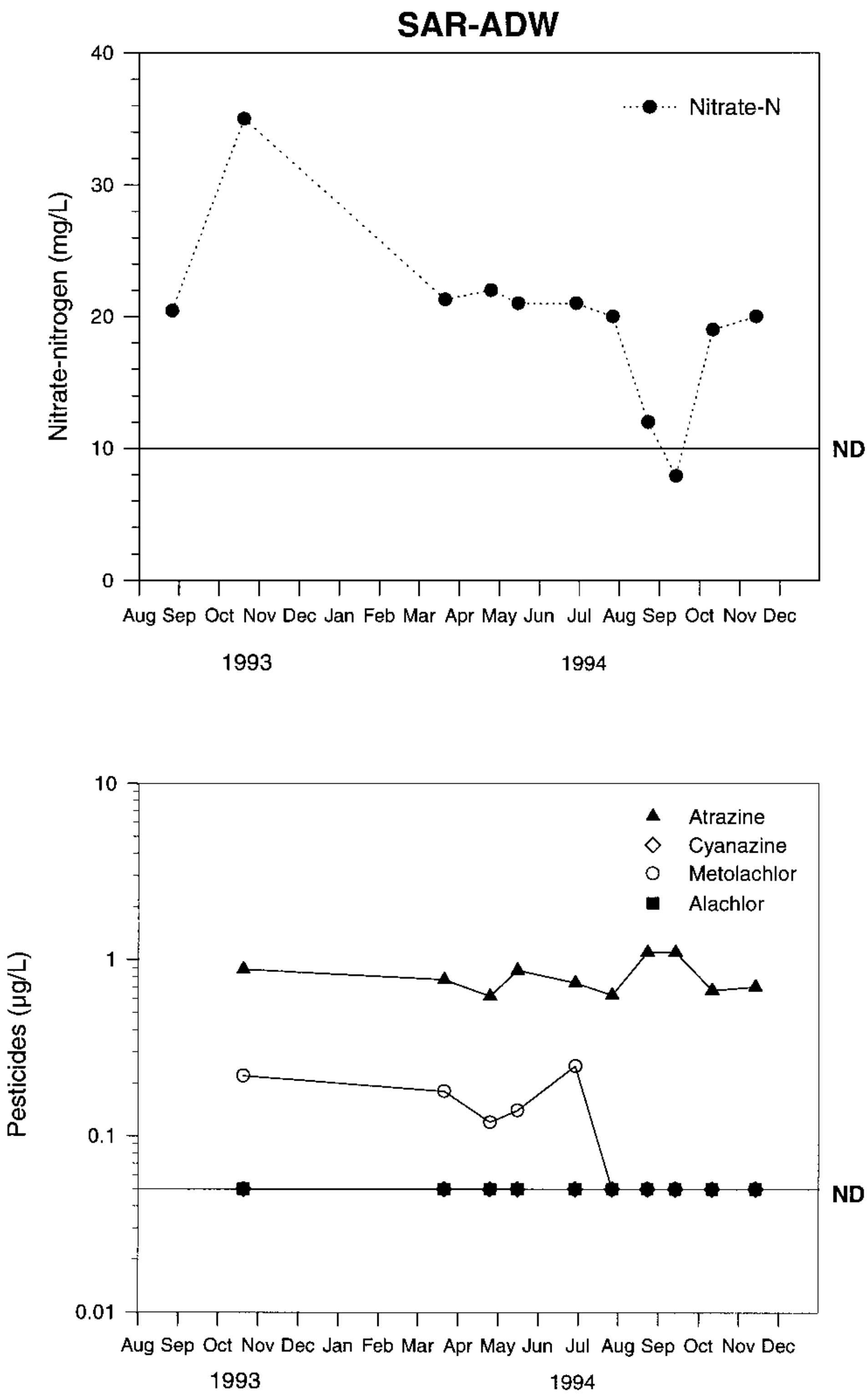
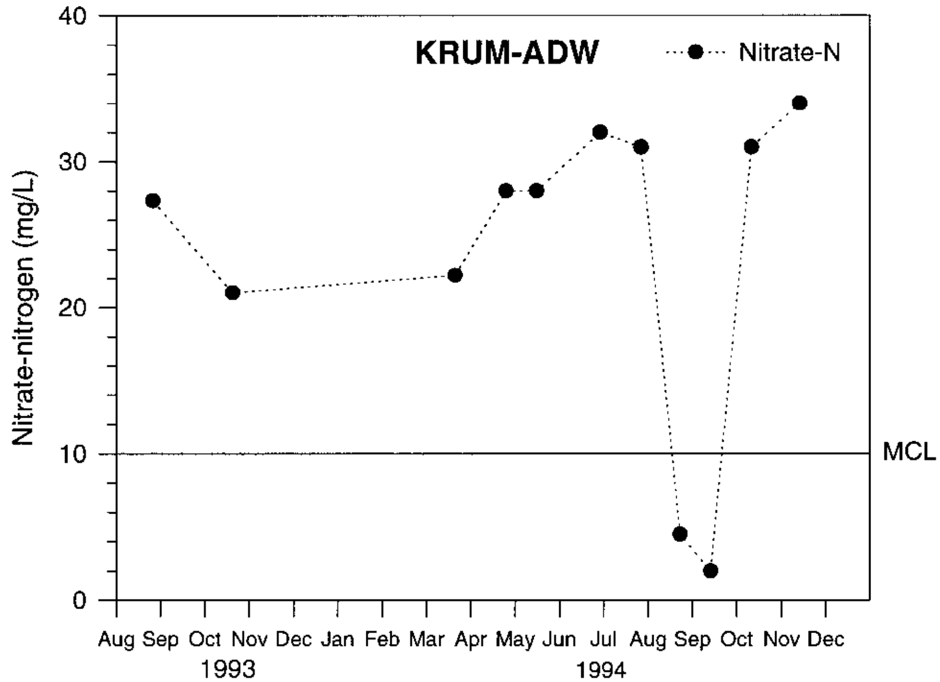


Figure 7. Nitrate-nitrogen and pesticide concentrations at SARR-ADW



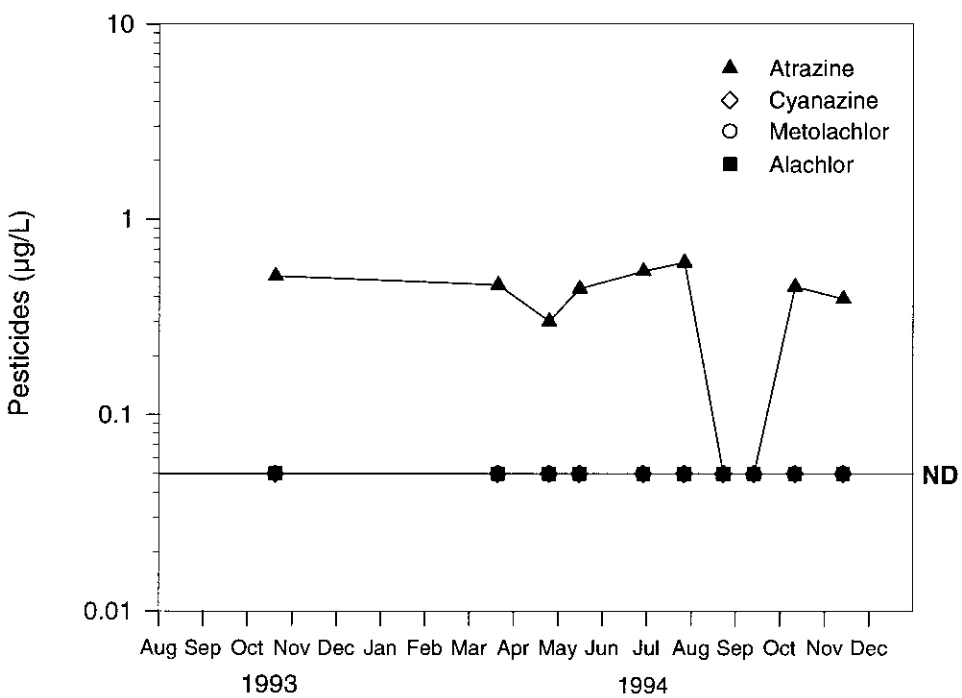


Figure 8. Nitrate-nitrogen and pesticide concentrations at KRUM-ADW.

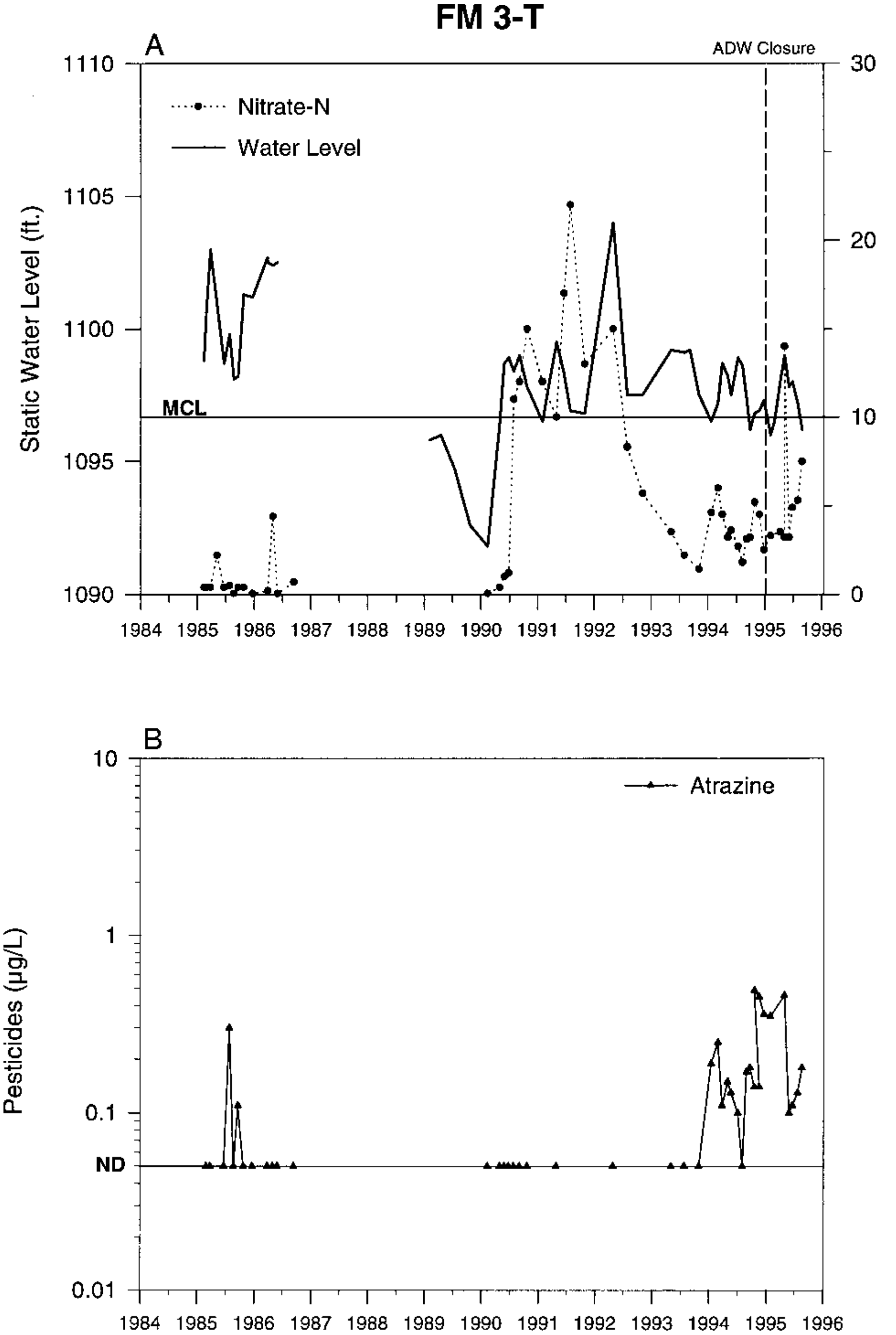


Figure 9. Nitrate-nitrogen and atrazine concentrations at KRUM-ADW.

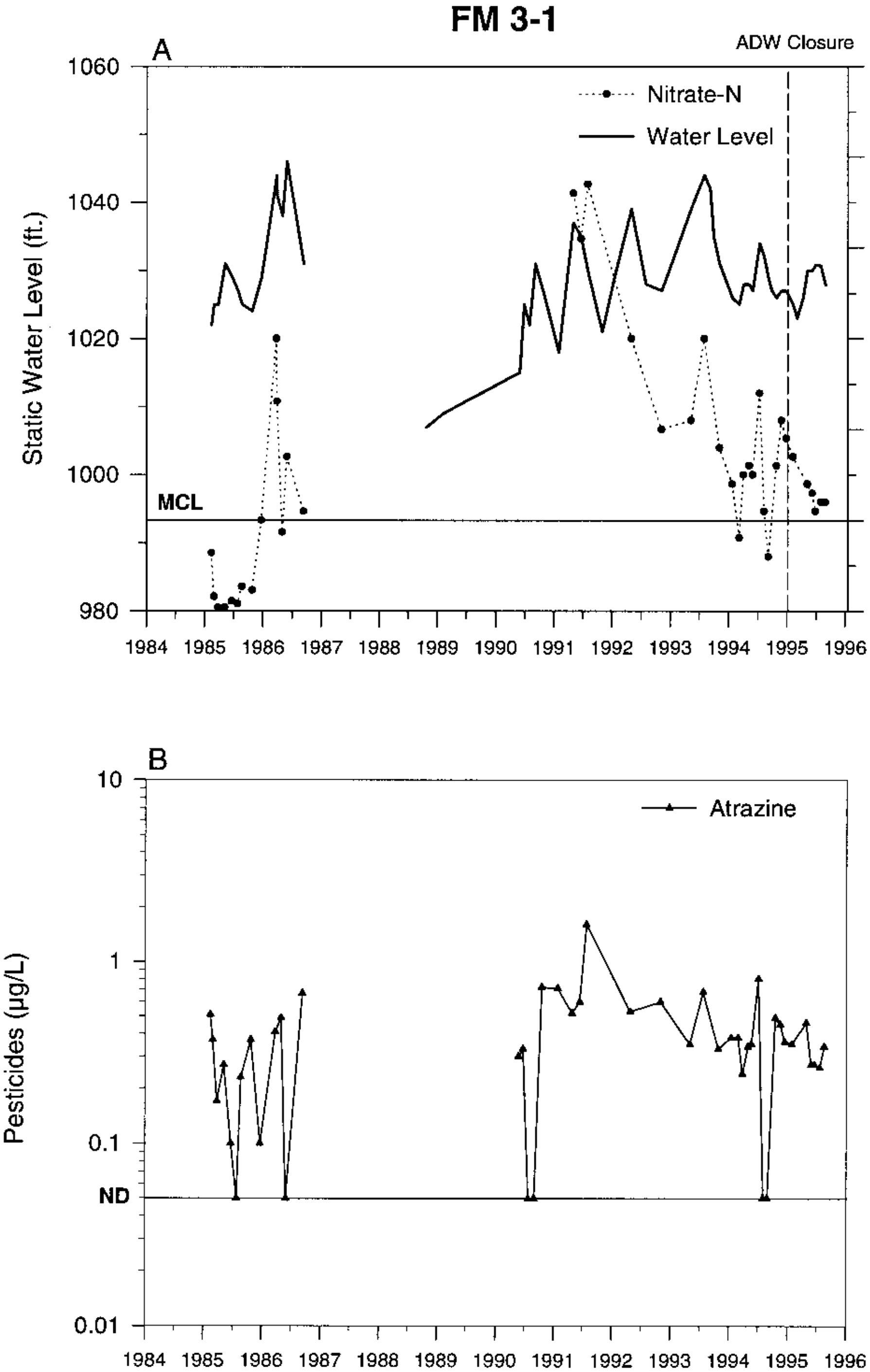


Figure 10. A) Static water levels, and nitrate-nitrogen concentrations, B) atrazine concentrations at the FM3-1 bedrock piezometer.

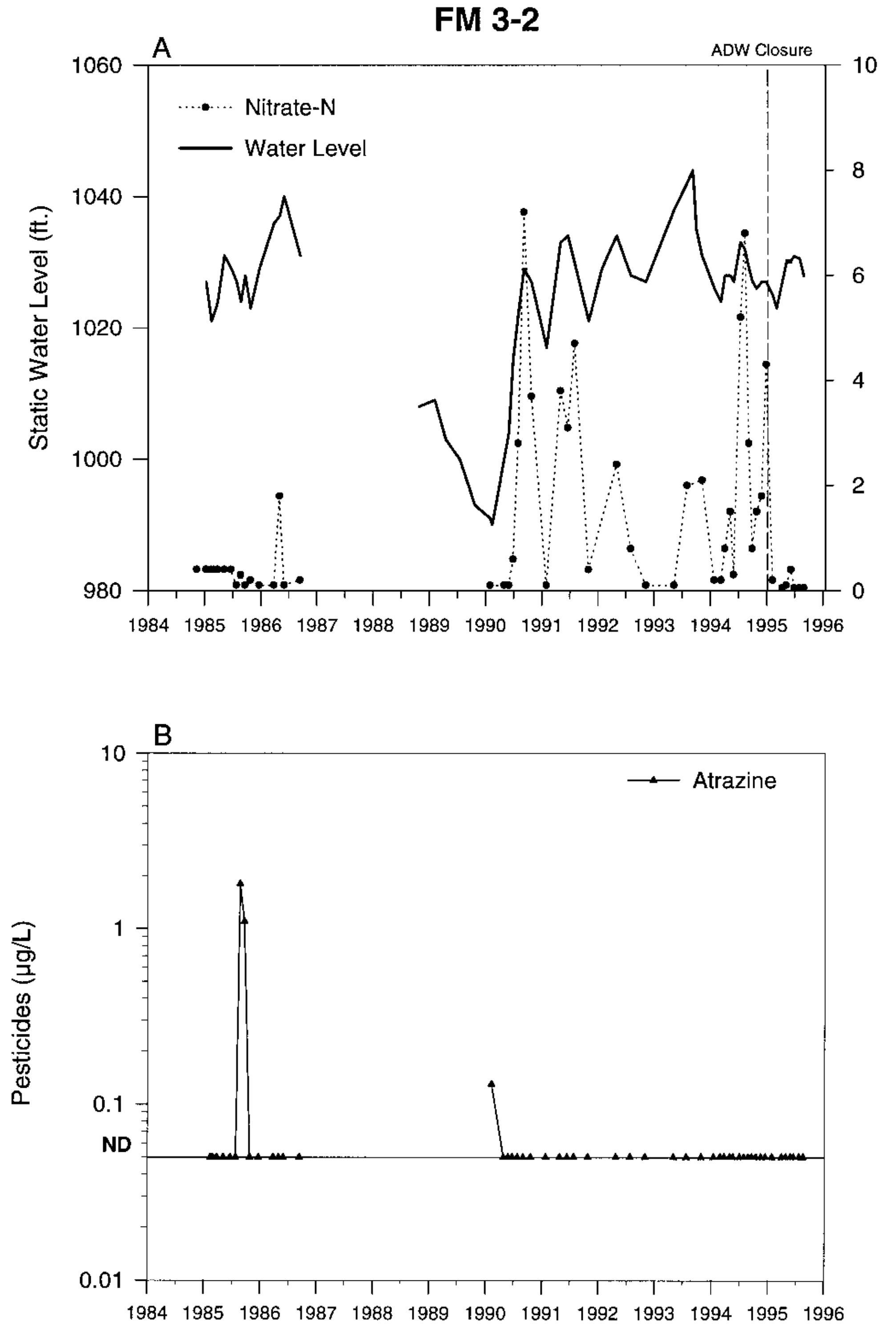


Figure 11. A) Static water levels, and nitrate-nitrogen concentrations, B) atrazine concentrations at the FM3-2 bedrock piezometer.

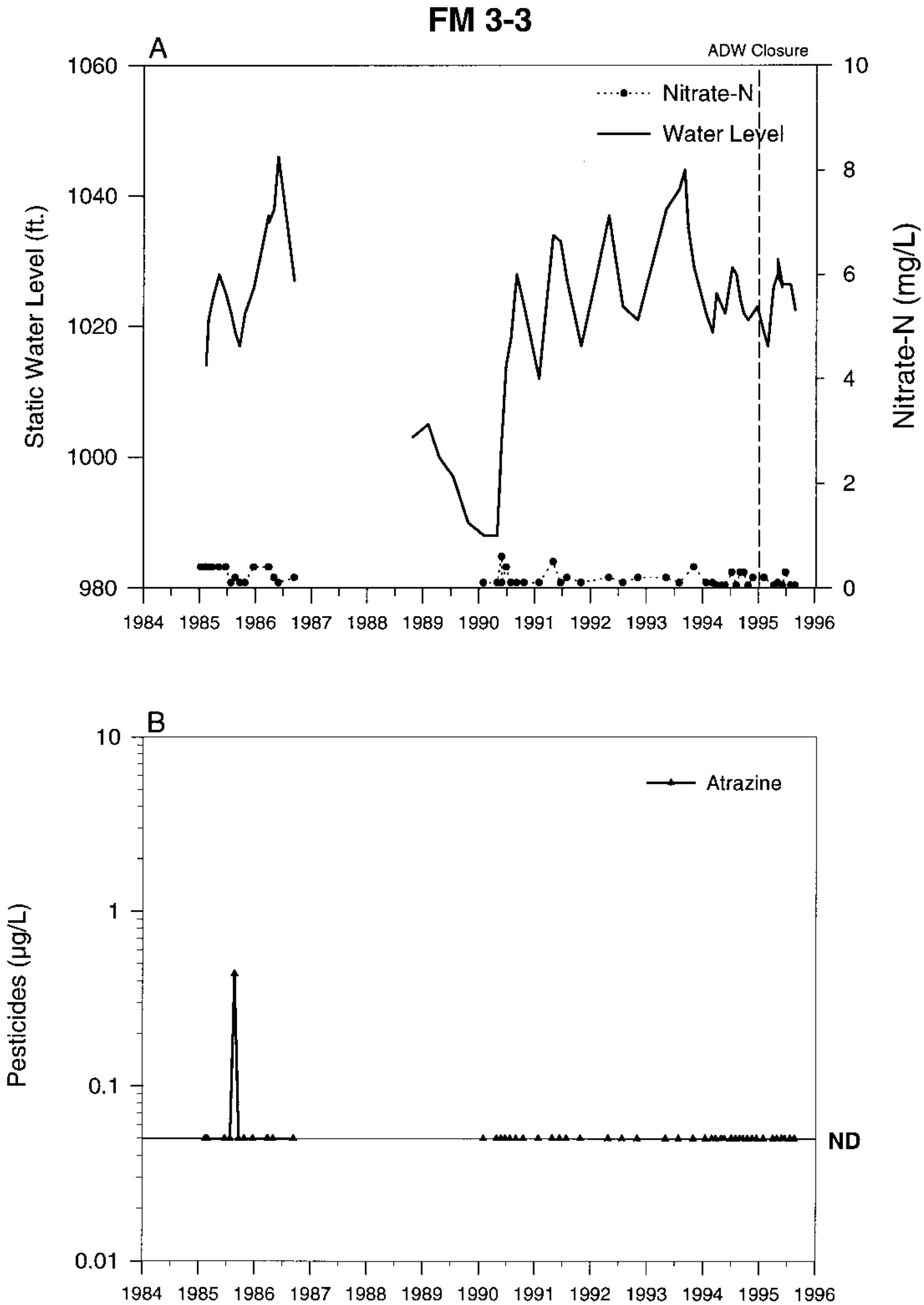


Figure 12. A) Static water levels, and nitrate-nitrogen concentrations, B) atrazine concentrations at the FM3-3 bedrock piezometer.

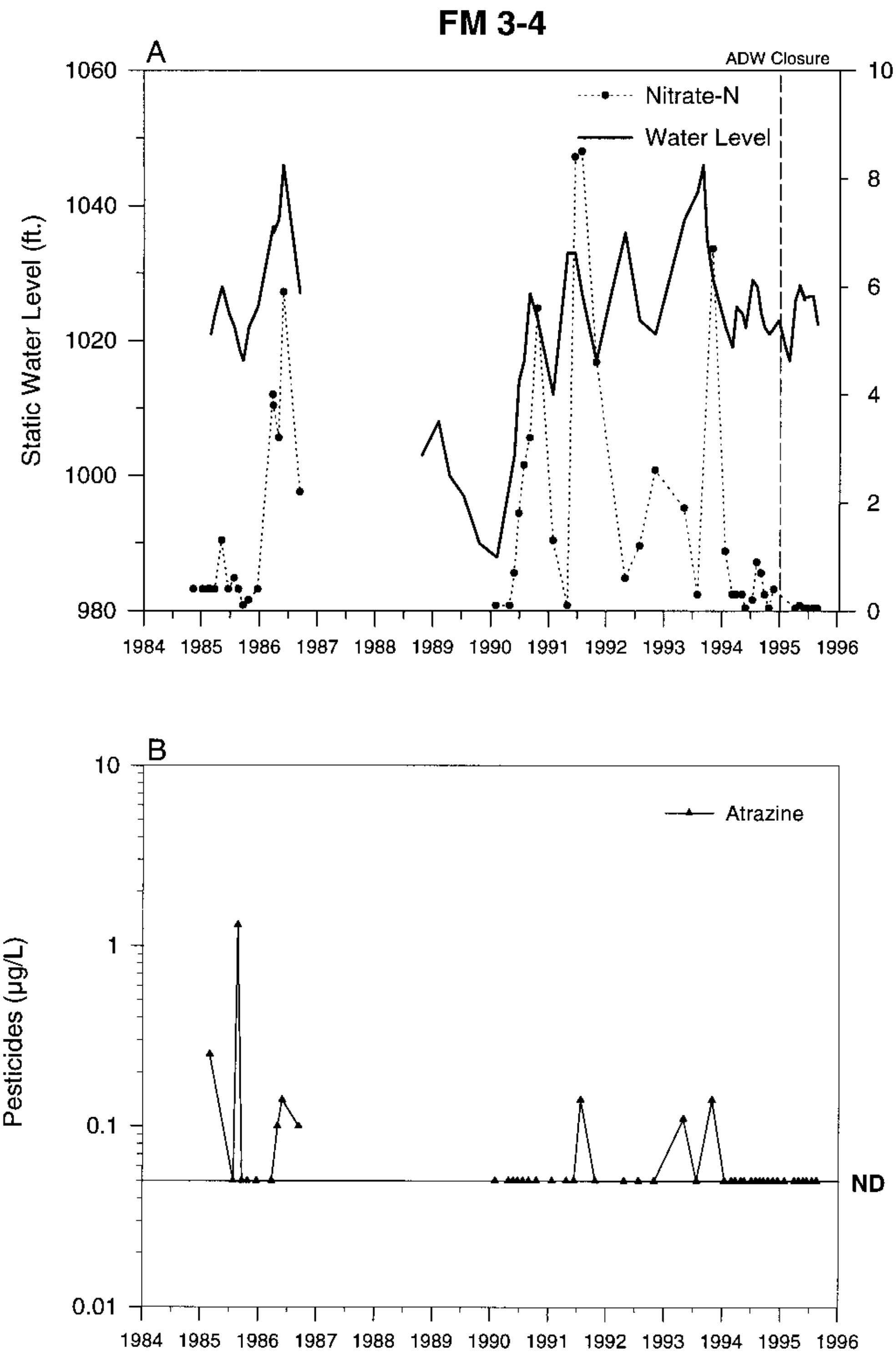


Figure 13. A) Static water levels, and nitrate-nitrogen concentrations, B) atrazine concentrations at the FM3-4 bedrock piezometer.

Table 3. Water-quality results from a bedrock piezometer nest in central Floyd County, IA.

Water-Quality Parameter	FM3-1	FM3-2	FM3-3	FM3-4
Number of samples:	38	45	46	46
Nitrate-N:				
number (%) sites >10 mg/L (HAL)	26 (68%)	0 (0%)	0 (0%)	0 (0%)
mean conc., mg/L	19.4	1.7	0.3	1.9
median conc., mg/L	16.5	0.8	0.3	0.7
max conc., mg/L	54	7.2	0.5	8.5
% of wells with nitrate-N>10 mg/L				
--- with an atrazine detection	21 (57%)	0 (--)	0 (--)	0 (--)
Number of samples:	37	43	41	39
Atrazine Detection:				
number (%) sites with detections	31 (84%)	3 (7%)	1 (2%)	8 (21%)
mean conc. of detections, µg/L	0.46	1.01	0.44	0.29
median conc., µg/L	0.38	1.10	--	0.14
max conc., µg/L	1.60	1.80	0.44	1.30
Any Pesticide Detection:				
number (%) sites with detections	31 (84%)	6 (14%)	2 (5%)	18 (46%)
Multiple Pesticide Detections:				
number (%) of sites with 2 or more detections	12 (32%)	0 (--)	0 (--)	9 (23%)

nitrate-N (Fig. 10). During such periods, the tile line draining to ADW-1 (and other observed tile outlets) was dry or supplying only a trickle of water. However, during the wet periods (i.e., Spring 1986 and Summer 1991) when heads at Site FM3 increased dramatically, nitrate concentrations in piezometer FM3-1 exceeded 30 mg/L to 45 mg/L NO_3-N at times, and changes in concentrations occurred very quickly. Piezometer FM3-4 also showed increased nitrate levels, to about 6 to 8 mg/L NO_3-N during similar recharge periods (Fig. 13). Piezometers FM3-2 and FM3-3 (Figures 11 and 12) showed little or no increases in nitrate-N, although the potentiometric response at these piezometers was similar to that which occurred in FM3-1 and FM3-4 (Fig. 10 and 13).

The increases in nitrate concentrations in some of the Site FM3 piezometers are interpreted as resulting from inputs from nearby ADWs during wet periods. The more significant response in the piezometer FM3-1, relative to others at Site FM3, may occur for several reasons. First, some nearby ADWs (KRUM-ADW and SARR-ADW) may not penetrate significantly deeper than FM3-1, and the water they deliver may only affect the upper part of the upper aquifer. Also, the uppermost bedrock at Site FM3 is unsaturated. ADW water entering this unsaturated zone is not subject to mixing and dilution with pre-existing water, as is the case with water entering deeper, saturated zones.

Comparison of the nitrate concentrations in the tile effluent at ADW-1 and in groundwater from the piezometers FM3-1 and FM3-4 (Fig. 14) yields insights about the complexity of the ADW-carbonate aquifer system. Note that the concentrations of nitrate measured going into ADW-1 during recharge periods are less than concentrations yielded by piezometer FM3-1. Also, concentrations and types of pesticides differ between the piezometers and ADW-1. This suggests that other ADWs, located farther away from Site FM3 than ADW-1 (such as KRUM-ADW, SARR-ADW and other nearby ADWs) may significantly impacting water quality at Site FM3.

Private Well Network.

Five private well sites (Figure 4) were selected for initial background monitoring and monitoring during the FM ADW Closure Project. The five wells are located in the protected, deep bedrock area and are within a two-mile radius of the FM3 piezometer nest; the wells have been sampled on a monthly basis since November 1994. These five wells are completed in the upper and middle Devonian aquifers. Figure 15 compares nitrate-N concentrations among five private wells and the shallow bedrock piezometer (FM3-1). At three of the private wells (C-Well, D-Well and Y-Well) and at the bedrock piezometer (FM3-1), which are within a mile radius of the ADW closures, it appears that nitrate-N concentrations have declined. The K-Well is completed in the middle aquifer and had negligible nitrate-N concentrations, similar to the concentrations found in FM3-2 and FM3-3 piezometers. Interestingly, the S-Well, which is the furthest private well site from the ADW closures (~2 miles), appears not to be impacted by ADW closures.

Pesticides

Table 4 lists the common chemical names and typical product names for the eight herbicides and two atrazine metabolites analyzed. Pesticide concentrations are reported in micrograms per liter of product (µg/L). Analyses were run on 88 samples of shallow groundwater and 160 samples from bedrock piezometers.

Shallow Groundwater

Table 2 provides summary statistics from pesticide monitoring of shallow groundwater sites. At FM3-T, 36% of the samples had at least one pesticide detected and 25% of the samples had two or more pesticides detected. These numbers increase at the tile line sites; 69% of the samples from ADW-1 had at least one pesticide detection and 44% of the samples had multiple pesticide detections. At nearby shallow ADWs, pesticide detections increase dramatically; at KRUM-ADW 80% of the samples had multiple pesticide detections and at SARR-ADW, 100% of the samples had multiple pesticide detections. At all shallow groundwater sites, atrazine and desethyl atrazine (an atrazine metabolite) were the most commonly detected pesticides, with a maximum atrazine concentration of 2.0 µg/L. Metolachlor, alachlor, cyanazine, and metribuzin were also detected with maximum concentrations of 5.90, 0.36, 2.80 and 0.73 µg/L, respectively (Table 5). Detections and multiple detections were more common and concentrations higher in samples collected from tile lines, compared to the till piezometer. Tile line water drains near the top of the water table while the till piezometer at site FM3 is completed below a paleosol that functions to some extent as an aquitard.

Bedrock Piezometers

Table 3 provides summary statistics from pesticide monitoring of bedrock piezometers. At FM3-1 and FM3-4, 84% and 46% of the samples had at least one pesticide detected and 32% and 23% of the samples had two or more pesticides detected. These numbers decrease dramatically at the FM3-2 and FM3-3; 14% and 5% of the samples had at least one pesticide detection and no samples had multiple detections at either site.

Figures 10 through 13 show concentrations of atrazine in bedrock piezometers. The atrazine data indicate that higher pesticide concentrations occur during wet, recharge periods; similar to the relationship for nitrate that was previously discussed. The highest and most persistent concentrations of atrazine occurred in piezometer FM3-1 (Fig. 10). Thirty-one of thirty-eight samples (84%) contained detectable atrazine, eight of thirteen samples (61%) had detectable desethyl atrazine and one of thirteen samples (8%) had detectable deisopropyl

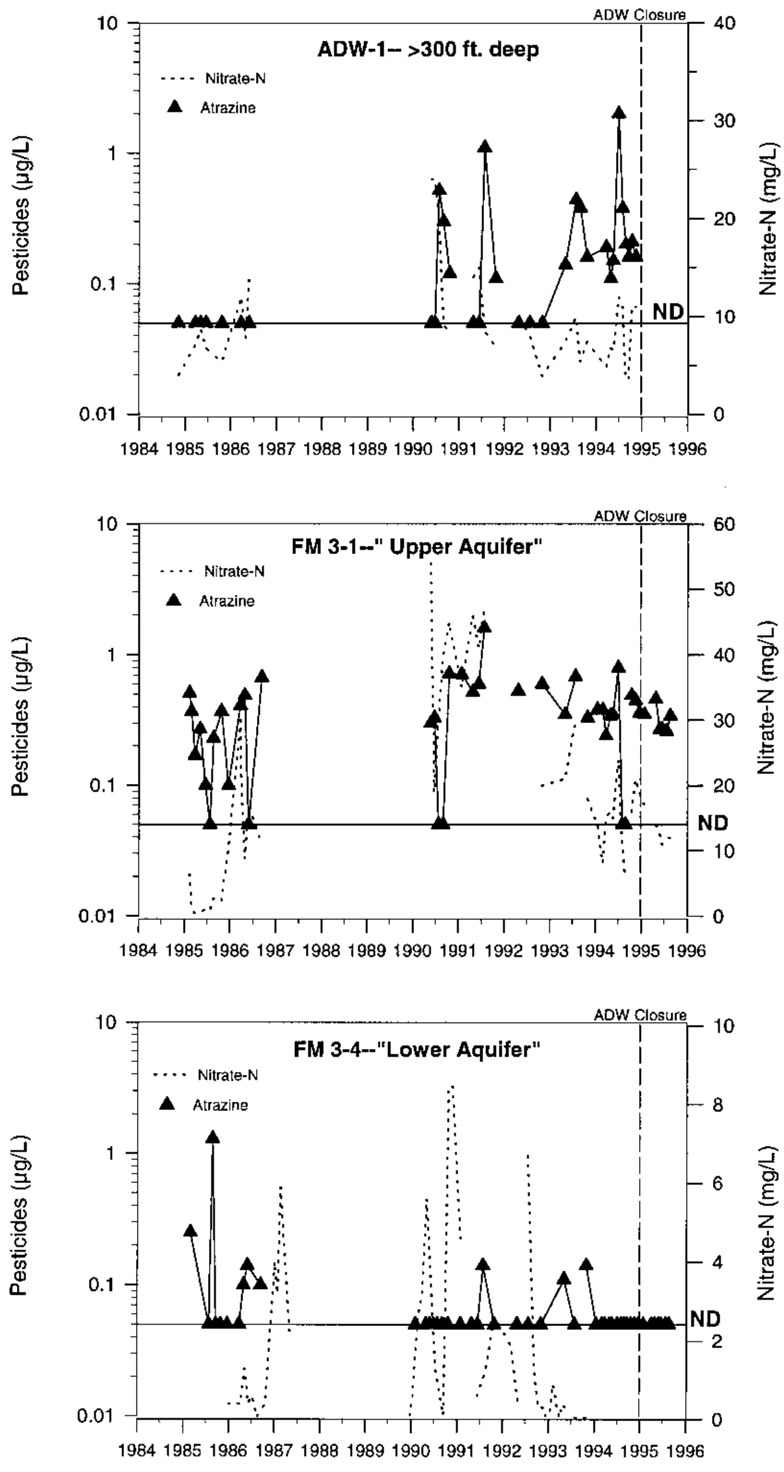


Figure 14. Nitrate-nitrogen and pesticide concentrations at ADW-1, FM3-1, and FM3-4.

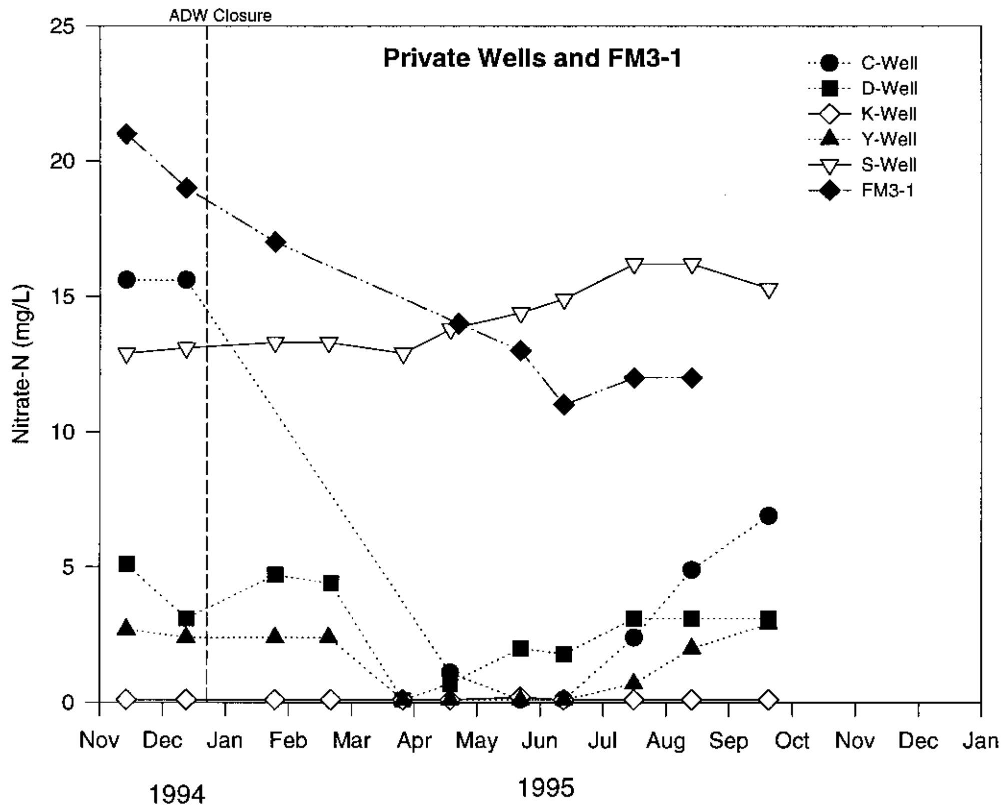


Figure 15. Nitrate-nitrogen at five private well sites (C,D,K, Y, S Wells) and at the bedrock piezometer FM3-1.

atrazine (Table 5). At site FM3-1 all pesticides analyzed for were detected during the course of sampling. Other pesticides more commonly detected during this period were metolachlor in 10 of 37 samples (27%), cyanazine, and alachlor detected in 3 of 37 samples (8%), and butylate in 2 of 37 samples (7%). Lower concentrations and detections of atrazine and atrazine metabolites occurred in piezometer FM3-4 (Fig. 13). Eight of forty-nine samples (21%) contained an atrazine detection and there were only two detections (4%) of the two atrazine metabolites (desethyl and deisopropyl atrazine). Only 3 of 43 samples (7%) from piezometers FM3-2 and 1 of 41 samples (2%) from FM3-3 contained atrazine. Other pesticides detected at piezometer FM3-2 and FM3-3 include several detections of alachlor and one detection of cyanazine (Table 6). Pesticide data parallels the nitrate data collected for bedrock piezometers; surficial contaminants were mostly detected in piezometers FM3-1 and FM3-4. Highest pesticide concentrations at FM3-1 and FM3-4 occurred during wet periods when tiles were discharging and high heads occurred (Figures 10 and 13). Site FM3 is located in a protected, deep bedrock areas, therefore ADWs are the likely source of agricultural contaminants in the groundwater samples.

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Table 4. Herbicides analyzed in current Floyd County study.

Chemical name	Typical product names
alachlor	Crop Star, Lasso, Partner
atrazine	Aatrex, Atrazine
butylate	Sutan
cyanazine	Bladex
desethyl atrazine	Atrazine metabolite
desisopropyl atrazine	Atrazine metabolite
metolachlor	Dual
metribuzin	Lexone, Sencor
trifluralin	Treflan, Tri 4

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Table 5. Water-quality results from shallow groundwater—tile lines and till piezometer.

Analytes	FM3-T	ADW-1	KRUM-ADW	SARR-ADW
Number of Samples:	36	32	10	10
Pesticides:				
number (%) sites with any pesticide detection	13 (36%)	22 (69%)	8 (80%)	10 (100%)
Atrazine (parent)				
number (%) sites with detections	12 (33%)	18 (56%)	8 (80%)	10 (100%)
mean conc., µg/L	0.16	0.38	0.46	0.81
median conc., µg/L	0.15	0.20	0.46	0.76
max conc., µg/l	0.30	2.00	0.60	1.10
HAL µg/L	3.00	3.00	3.00	3.00
Desethyl atrazine				
number (%) sites with detections	10 (91%)	12 (92%)	8 (80%)	10 100%)
mean conc., µg/L	0.26	0.20	0.79	1.13
median conc., µg/L	0.26	0.17	0.82	1.15
max conc., µg/l	0.4	0.4	0.8	1.4
Deisopropyl atrazine				
number (%) sites with detections	2 (6%)	0 (--)	0 (--)	0 (--)
mean conc., µg/L	4.55	--	--	--
median conc., µg/L	4.55	--	--	--
max conc., µg/l	8.90	--	--	--
Alachlor (Lasso)				
number (%) sites with detections	0 (--)	2 (6%)	0 (--)	0 (--)
mean conc., µg/L	--	0.24	--	--
median conc., µg/L	--	0.24	--	--
max conc., µg/l	--	0.36	--	--
HAL µg/L	0.40	0.40	0.40	0.40
Metolachlor (Dual)				
number (%) sites with detections	0 (--)	5 (16%)	0 (--)	5 (50%)
mean conc., µg/L	--	1.36	--	0.18
median conc., µg/L	--	0.18	--	0.18
max conc., µg/l	--	5.90	--	0.25
HAL µg/L	100.0	100.0	100.0	100.0
Cyanazine (Bladex)				
number (%) sites with detections	0 (--)	2 (6%)	0 (--)	0 (--)
mean conc., µg/L	--	1.46	--	--
median conc., µg/L	--	1.45	--	--
max conc., µg/l	--	2.80	--	--
HAL µg/L	1.00	1.00	1.00	1.00

Table 5. Continued.

Analytes	FM3-T	ADW-1	KRUM-ADW	SARR-ADW
Metribuzin (Sencor)				
number (%) sites with detections	0 (--)	1 (3%)	0 (--)	0 (--)
mean conc., µg/L	--	0.73	--	--
median conc., µg/L	--	--	--	--
max conc., µg/l	--	0.73	--	--
HAL µg/L	200.0	200.0	200.0	200.0
Trifluralin (Treflan				
number (%) sites with detections	0 (--)	0 (--)	0 (--)	0 (--)
mean conc., µg/L	--	--	--	--
median conc., µg/L	--	--	--	--
max conc., µg/l	--	--	--	--
HAL µg/L	2.00	2.00	2.00	2.00
Butylate (Sutan)				
number (%) sites with detections	0 (--)	0 (--)	0 (--)	0 (--)
mean conc., µg/L	--	--	--	--
median conc., µg/L	--	--	--	--
max conc., µg/l	--	--	--	--
HAL µg/L	700.0	700.0	700.0	700.0

Table 6. Water-quality results from four bedrock piezometers.

Analytes	FM3-1	FM3-2	FM3-3	FM3-4
Number of Samples:	37	43	41	49
Pesticides:				
number (%) sites with any pesticide detection	31 (84%)	6 (14%)	2 (5%)	4 (10%)
Atrazine (parent)				
number (%) sites with detections	31 (84%)	3 (7%)	1 (2%)	8 (21%)
mean conc., µg/L	0.46	1.01	0.44	0.29
median conc., µg/L	0.38	1.10	--	0.14
max conc., µg/l	1.60	1.80	0.44	1.30
HAL µg/L	3.00	3.00	3.00	3.00
Desethyl atrazine				
number (%) sites with detections	8 (61%)	1 (9%)	0 (--)	2 (4%)
mean conc., µg/L	0.58	0.10	--	0.15
median conc., µg/L	0.54	--	--	0.15
max conc., µg/l	0.90	0.10	--	0.15
Deisopropyl atrazine				
number (%) sites with detections	1 (8%)	0 (--)	0 (--)	0 (--)
mean conc., µg/L	18.00	--	--	--
median conc., µg/L	--	--	--	--
max conc., µg/l	18.00	--	--	--
Alachlor (Lasso)				
number (%) sites with detections	3 (8%)	2 (5%)	1 (2%)	1 (2%)
mean conc., µg/L	0.95	0.13	0.19	0.48
median conc., µg/L	0.21	0.13	--	--
max conc., µg/l	2.50	0.15	0.19	0.48
HAL µg/L	0.40	0.40	0.40	0.40
Metolachlor (Dual)				
number (%) sites with detections	10 (27%)	0 (--)	0 (--)	16 (33%)
mean conc., µg/L	0.26	--	--	0.21
median conc., µg/L	0.24	--	--	0.16
max conc., µg/l	0.49	--	--	0.87
HAL µg/L	100.0	100.0	100.0	100.0
Cyanazine (Bladex)				
number (%) sites with detections	3 (8%)	1 (2%)	0 (--)	4 (10%)
mean conc., µg/L	0.30	0.31	--	0.35
median conc., µg/L	0.20	--	--	0.33
max conc., µg/l	0.55	0.31	--	0.63
HAL µg/L	1.00	1.00	1.00	1.00

Table 6. Continued.

Analytes	FM3-1	FM3-2	FM3-3	FM3-4
Metribuzin (Sencor)				
number (%) sites with detections	1 (3%)	0 (--)	0 (--)	0 (--)
mean conc., µg/L	0.42	--	--	--
median conc., µg/L	--	--	--	--
max conc., µg/l	0.42	--	--	--
HAL µg/L	200.0	200.0	200.0	200.0
Trifluralin (Treflan				
number (%) sites with detections	1 (3%)	0 (--)	0 (--)	0 (--)
mean conc., µg/L	0.12	--	--	--
median conc., µg/L	--	--	--	--
max conc., µg/l	0.12	--	--	--
HAL µg/L	2.00	2.00	2.00	2.00
Butylate (Sutan)				
number (%) sites with detections	2 (7%)	0 (--)	0 (--)	0 (--)
mean conc., µg/L	0.65	--	--	--
median conc., µg/L	0.65	--	--	--
max conc., µg/l	0.83	--	--	--
HAL µg/L	700.0	700.0	700.0	700.0

FLOYD COUNTY GROUNDWATER PROTECTION PROJECT AGRICULTURAL DRAINAGE WELLS

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Agricultural Drainage Wells (ADWs) are used to outlet tile drainage water from crop fields into underlying groundwater aquifers. Most wells were installed between 1920 and 1960 before usage of fertilizers and pesticides became widespread. The majority of the ADWs are located in four counties in Iowa: Floyd, Humboldt, Pocahontas, and Wright. In Floyd County, 92 wells were registered with either the Environmental Protection Agency (EPA) or the Department of Natural Resources (DNR). Of these 92 wells, 24 were found to be either non-functioning, closed, or non-existent. In the end, 68 ADWs were still considered active. Figure 1 is a map of Floyd County that shows the locations of known sinkholes and ADWs.

The Floyd County Groundwater Protection Project provided cost-share for alternate outlets for ADWs in the county. Nineteen wells have been or will be closed by the spring of 1996, leaving 49 active wells in the county.

Stop 6a of this field trip is the site of three ADWs which were closed in the fall of 1994. These three wells utilized a common tile line which outlets in a county road ditch. The cost of this project was $15,031 which does not include the portion provided by Floyd County, the landowner's improvement to their drainage ditch, staff time, or legal fees.

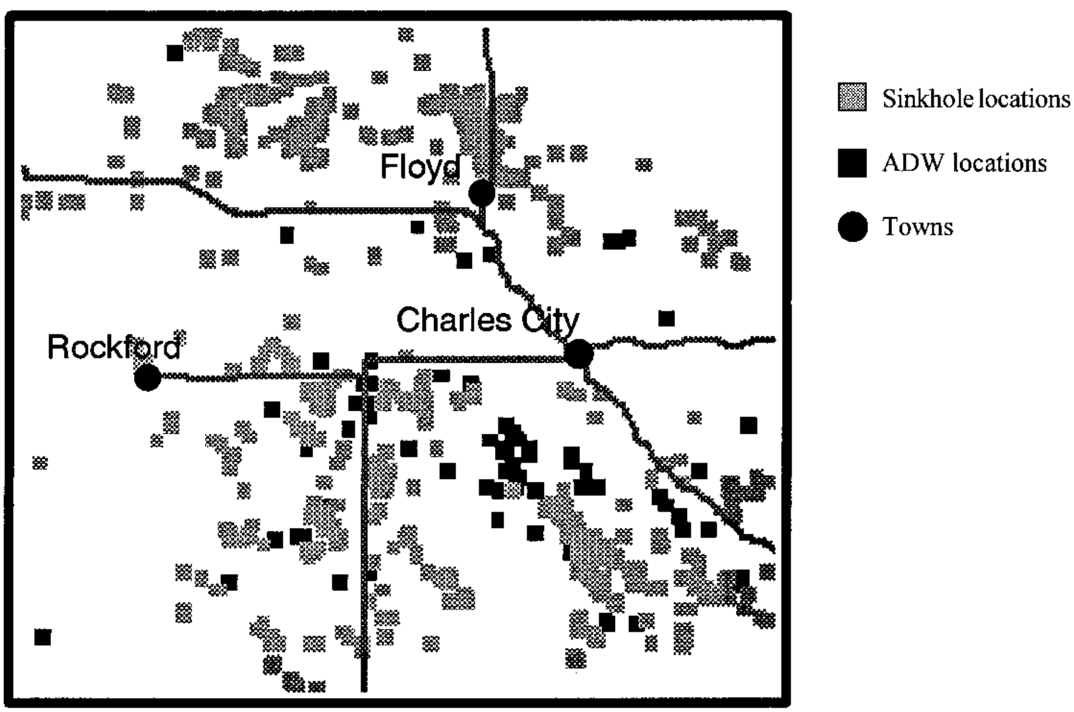


Figure 1. Map of Floyd County showing the locations of known sinkholes and ADWs.

KEY

Major Lithologies:

- limestone
- "sublithographic" limestone (micritic or pelletal)
- irregularly bedded limestone
- coral or stromatoporoid-rich limestone (biostrome)
- laminated limestone
- highly fractured to brecciated brecciated or intraclastic
- shale partings argillaceous

Other lithologic modifiers:

- hardground surface
- stylolites
- b "birdseye"
- v vuggy
- c calcite void fill
- P phosphate
- g glauconitic
- m mudstone
- sandy
- intraclasts, lithoclasts
- cross-bedded
- chert
- "stromatactis" structures
- voids or fractures filled with laminated internal sediment

Fossils:

- digitate stromatoporoids ("*Idiostroma, Amphipora*")
- hemispherical or laminar stromatoporoids
- T colonial tabulate corals (favositids)
- t small tabulate corals
- colonial rugose corals (*Hexagonaria*)
- solitary rugose corals
- overturned corals and stromatoporoids
- brachiopods
- # bryozoans
- gastropods
- bivalves
- crinoid debris
- crinoidal limestone
- trilobites
- fish teeth, plates
- plant debris
- burrows
- nautiloids

The Lithograph City Enterprise

VOLUME 1 | LITHOGRAPH CITY, FLOYD COUNTY, IOWA, THURSDAY SEPTEMBER 28, 1916 | NUMBER 17

Wonderful Lithograph City

by Belle Caldwell, Charles City, Iowa

The following article was published Sunday, September 17th, in the Des Moines Register and Leader, with illustrations. The cases, etc., spoken of are now in place and the building open to the public.

"Imagine you are taking an automobile tour and in one place on your route you go down a hill and before you is a beautiful valley with a little town similar to the mushroom growth ones of the far west. Of course you make a little detour off the main road and enter this little town. A large building attracts your attention ---- on its front you see a large sign, above the door, "Museum."

"What! A museum way out here on the prairie, away from a railroad even, and in this little town? Why museums are always located in cities and in connection with universities. What can this be? You think or say to your companions, and naturally, your curiosity prompts you to enter the museum.

Here you find the largest private collection of geological specimens in America.

The building is crowded with semiprecious gems, and minerals from all parts of America and foreign countries.

This is not the beginning of a fairy tale, ancient or modern, nor a modern day novel, but a statement of actual facts. The museum is located in Lithograph City, Floyd county, fourteen miles northwest of Charles City. It is the private collection of Clement L. Webster, gathered by him in his geological excursions in all parts of North America during the last thirty-five years and by gifts and exchange with foreign countries.

The building is 22x50 feet, two stories high and with a 50-foot basement. The cases and shelving for the upper floor are now in the course of erection and will soon be completed, when there will be over 3,880 feet of wall and horizontal shelving and glass cases down the center of each floor.

The Smithsonian institution at Washington furnished the blue prints free for the building and is taking great interest in the museum. It has only been completed a few months, but during that short period nearly 5,000 people have visited it and at the lowest estimate 300 automobiles from other states than Iowa have stopped here to see the museum, some from as distant points as New York and California.

Among them was a lumber king and his party from the west who were so interested in this wonderful and unique collection and building that they plan to make it another visit when it is entirely completed. Scientists from all over the United States have come here especially to see the collection, and this summer two experts from the United States Geological Survey came from Washington to see it and the geological formations of the immediate vicinity. These experts pronounced it the greatest thing of the kind they had ever seen.

In the museum are specimens of all the soils, subsoils, clays, sands and gravels of this state, so that the agricultural interest of Iowa have here in one place as fine a survey of the products as could be gained in prospecting in several years time.

In the museum, specimen bottles are also exhibited of the different fertilizers to be found in Iowa. The principal kind is a calcium carbonate fertilizer, of two different grades. Some day it will be vitally important to know the valuable fertilizers that can be obtained in our own state for its much used soil.

Sixty-five per cent of the geological specimens are from Iowa and this makes the museum unique in America, as in no other state are there gathered together in one place such a representation of its geology and soils as here.

Here is the largest and best collection in existence of the Hackberry fossils, which are absolutely an Iowa product, being found in no other locality but Iowa. The Hackberry fossils have been the subject of research and study by Mr. Webster for a number of years and were named by him after Hackberry. Previous to his researches in the Hackberry fossils, only forty or fifty species had been discovered. He has collected and has on exhibition here over 200, not to be found in any other locality than Iowa. This collection alone fills fifty feet of horizontal cases and a wall case.

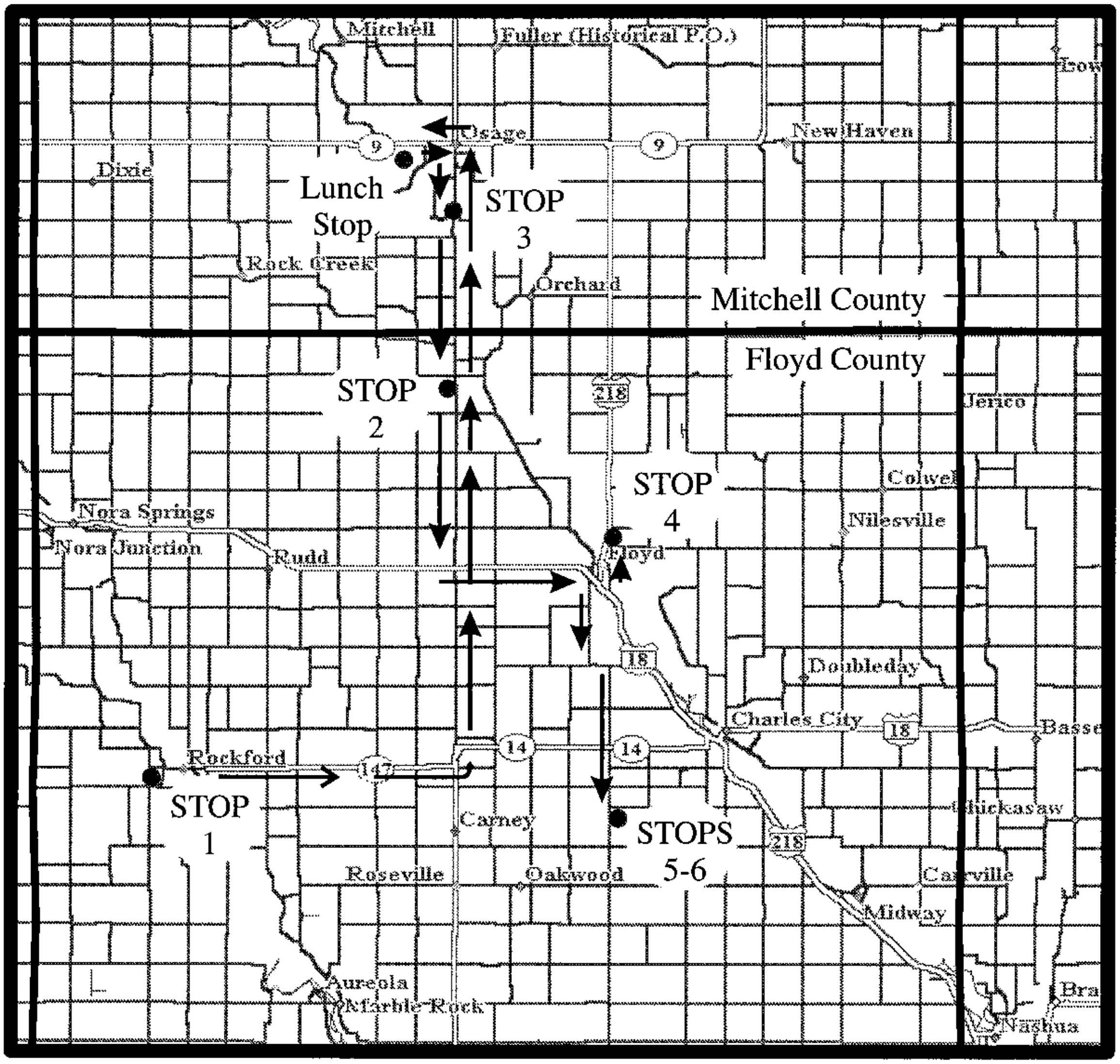
A large wall case is filled with exhibits from the mounds of Floyd county which a few years ago were explored by Mr. Webster and the many rare specimens of the lowest type of man known and of stone implements and other specimens of the prehistoric age were here obtained and are now on display in the museum. Here one may study history from the first dawn of life to the present time.

Among the exhibits of other states is one of several thousand specimens of the Texas cretaceous period, and marbles of different European countries, semi-precious gems of great variety, minerals, shells and various other collections of geological specimens and fossils from different localities and periods of time. One of the finest collections of crystals to be found in any museum may be seen here, and specimens of all sizes of the lithographic stone found in this section of the state. In quantities, sizes and degree of fineness and color, the Iowa stone surpasses that found anywhere else in the world, outside of Solenhofen, Bavaria, Germany, and in America except in a small bed in Kentucky, which is not to be compared for extent and size and quality of stone quarried.

Lithograph City is named for the lithographic stone found there and of which four quarries are now being worked. The plant includes one of the largest stone-crushing establishments in the state and a staff for the polishing and cutting of marble and lithographic stone. Stones of a very large size have been quarried, the largest being 5x9 feet and eight inches thick, which is four times as large as the largest lithograph press can use.

Marbles to the number of twenty-three different kinds are also found here in quantities to make it of commerical importance. As far back as 1886 a report on ornamental stones of the United States, by the national museum at Washington, speaks of the marbles of the Devonian beds found near Charles City, as being among the most unique found in this country. Several different varieties of semi-precious gems are found here in a good size, such as sard, cornelian, heliotrope, and onyx.

The Webster museum is not only of great value and importance to Iowa, but is of national importance.



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