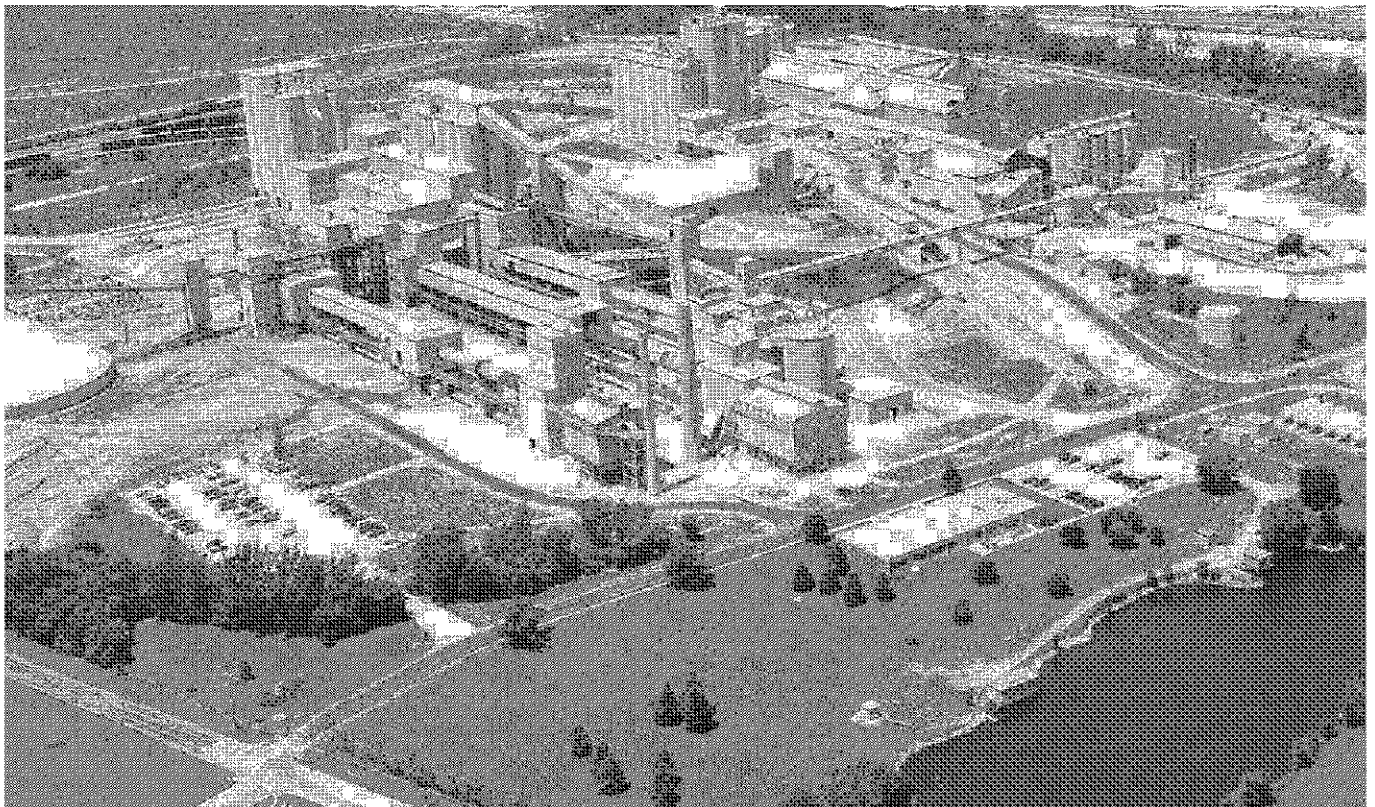


# **FOSSIL SHELLS, GLACIAL SWELLS, PIGGY SMELLS, AND DRAINAGE WELLS: THE GEOLOGY OF THE MASON CITY, IOWA, AREA**

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edited by Raymond R. Anderson and Bill J. Bunker



Holnam Inc. Mason City Cement Plant

**Geological Society of Iowa**

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April 26, 1998

Guidebook 65

**Cover photograph:** Aerial photograph of the Holnam In. Mason City Cement Plant. The two large cement kilns are visible at the left end of the complex near the center of the photograph. A tour of the cement plant is **Stop 2B** of the field trip.

Photograph courtesy of Holnam Inc.

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THE GEOLOGY OF THE MASON CITY, IOWA, AREA**

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**Geological Society of Iowa  
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## JOHN LEMISH 1921 – 1998

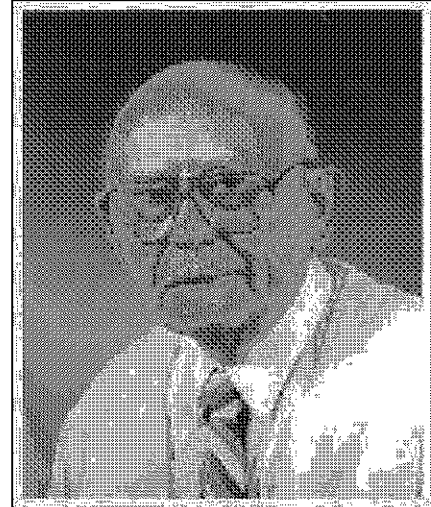
The Geological Society of Iowa and the entire Iowa geological community lost a colleague and a good friend with the passing of Professor John Lemish (Iowa State University) on March 22, from complications associated with Parkinson's Disease. John was born in Rome, New York, on the Fourth of July in 1921. He started pursuit of a degree in chemical engineering at the University of Michigan in 1941, but his education was interrupted by World War II when in 1942 he joined the US Army Air Force. By April of 1944 he had graduated from twin engine flying school and went on to serve as a B-17 bomber pilot in the 851<sup>st</sup> Squadron, 490<sup>th</sup> Bomb Group in the 8<sup>th</sup> Air Force. He flew 29 combat missions over Germany, earning the rank of 1<sup>st</sup> lieutenant, the air metal with 4 clusters, and the European theater ribbon with 3 clusters. In 1945 John was discharged from the Air Force, and he returned to the University of Michigan where he soon switched his major to geology and earned his BS (1947), MS (1948), and PhD in economic geology (1955).

Upon his graduation John served as a teaching fellow at the University of Michigan, working summers with the US Geological Survey, first with J. Hoover Mackin in the Iron Springs District, Utah, and Tom S. Lovering on the East Tintic Project near Eureka, Utah. In 1955 he joined the faculty of Iowa State as an Associate Professor of Geology, specializing in economic and structural geology and geochemistry, becoming a full Professor in 1962. John's professional interests included the behavior of carbonate aggregates in highway concrete, coal occurrence, exploration and gasification, gypsum and limestone exploration, and dolomitization. His teaching responsibilities included classes in economic geology, oceanography, geology of Iowa, fossil fuels, mineral resources, structural geology, engineering geology, petrology, optical mineralogy and many other classes. In 1983 John became a Research Associate with the Fossil Energy Program of the Ames Laboratory, retiring as Professor Emeritus in 1991.

John was a member of a number of professional organizations and was appointed to the State Mining Board by Governor Harold Hughes in 1964, serving until 1973. With his wife Jane he wrote a novel "Jeff Carson – Young Geologist, published in 1960.



John Lemish at the Roberts Creek Quarry, west of Farmersburg in Clayton Co. 1986 GSI Fall Field Trip



JOHN LEMISH (1921-1998)

A great friend of the Geological Society of Iowa, John and his students attended many of our field trips. One of the memorable moments with John occurred on April 24, 1983. Brian Witzke, Gil Klapper, and Bill Bunker were leading a heated discussion on the dolomitization of Silurian carbonates at the Highway 150 road cut just south of the Turkey River near Eldorado in Fayette County. John, a long-time student of dolomitization processes, quelled the discussion with "*Well, if Mother nature wants the rocks dolomitized, well, by God, she'll get the job done*". Who are we to argue. John we will miss you.

John is survived by a son Jeffrey who lives in Ames, four daughters, and three sisters.

Raymond R. Anderson  
Geological Society of Iowa

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### **ACKNOWLEDGEMENTS**

The authors, trip leaders, and field trip participants wish to thank Holnam Inc. for allowing us access to their quarry and cement production facilities (Stop 2). We especially thank Steve Otto, Chief Chemist for Holman Inc., for his assistance and for guiding us through the cement plant. We would also like to thank landowners Dave and Holly Thompson for allowing the group to visit their farm and thank them for their continued interest and cooperation in the monitoring project. GSB staff has had a unique opportunity to monitor this particular site and increase our understanding as to how an earthen storage basin functions on the Des Moines Lobe. Finally, thanks to Bill Drury of the Wright County Soil and Water Conservation District for arranging stop 6.

## INTRODUCTION

As the title implies, this **Geological Society of Iowa** Spring Field Trip will provide participants with and opportunity to examine aspects of the stratigraphy, economic geology, and environmental geology in Cerro Gordo, Hancock, and Wright counties. A series of six stops are planned, with the morning devoted primarily to bedrock geology, including a look at Upper Devonian units and a tour of a cement plant. Our lunch stop and post-lunch stops will examine quaternary features and the effects of large-scale confinement hog farming on the local water quality.

**Stop 1** will be at the famous Bird Hill State Geological Preserve on County Road B47, about 7 miles south of Nora Springs. The Cerro Gordo and Owen members of the Devonian Lime Creek Fm. are exposed at Bird Hill, but the preserve is most famous for the "*...hoards of superbly preserved fossils, relicts of warm shallow seas, (that) weather free from the soft shales and limestones of the local bedrock*" (Anderson and Furnish, 1987). These fossils constitute the famous Hackberry fauna, well over 100 species of corals, echinoids, bryozoans, brachiopods, and other fossils. Collecting is allowed.

**Stop 2** will be in Mason City at the Holnam Inc. limestone quarry where we observe and collect the rocks and fossils from the Devonian Lithograph City and Shell Rock formations. The second part of this stop will be a tour of the company's cement plant just south of the mine.

**Stop 3** will be at Clear Lake where Art Bettis will describe the geology of the lake as we enjoy our lunch.

The first stop of the afternoon (**Stop 4**) will be at Pilot Knob State Park in north-central Hancock County. One of the highest points in Iowa, this stop will provide a view the irregular hummocks and kettle depressions on the Altamont ice moraine, as well as Pilot Knob, a glacial kame. If time permits we will visit Dead Man's Lake, one of Iowa's most unusual wetlands and a nutrient-poor fen,

Next we will travel south to **Stop 5** in the southern part of Hamilton County near Twin Lakes for one of the more unusual GSI stops, a confinement hog feeding operation. In the early 1990s, Iowa saw an industry-wide move to larger scale hog-confinement operations. Within several years, the public was expressing concern over the social, economic, and environmental issues surrounding the rapid increase of these facilities. We will visit the Thompson farm to view their family-owned 4,500-hog finishing operation. The shallow groundwater near their earthen manure storage basin has been monitored by the DNR since 1994 to provide seepage and contamination information. We will view their operation and discuss the environmental problems associated with this type of farming.

The last stop of the day (**Stop 6**) will also provide a forum for the discussion of groundwater protection issues. It will be in northern Wright County where we will be introduced to agricultural drainage wells (ADWs) and the issues and concerns associated with them. The siting of several multi-million gallon earthen manure-storage lagoons in close proximity to agricultural drainage wells has focused attention on the risk that ADWs pose to Iowa's groundwater resources. In the area, 25 ADWs are located within one mile of large-scale hog-confinement operations, some within one-quarter mile. At this stop we will discuss the Des Moines Lobe landscape area and the problems associated with the siting of animal facilities in this area.





## STOP 1: LIME CREEK FORMATION AT BIRD HILL

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### *Introduction*

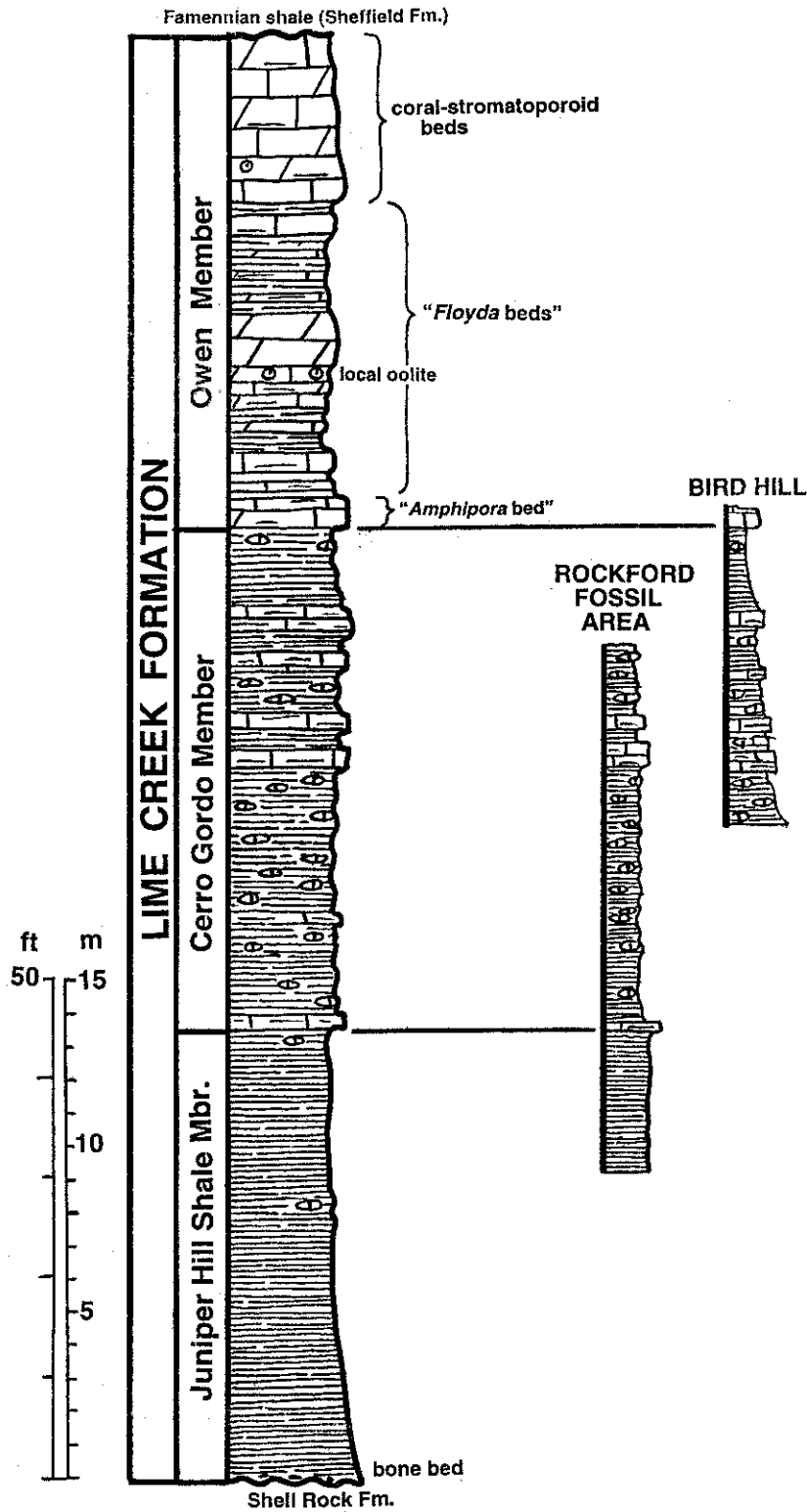
The Lime Creek Formation of northern Iowa is world-renowned for its remarkably rich fossil fauna. It is an Upper Devonian rock unit (late Frasnian age). The formation derives its name from Lime Creek, now termed the Winnebago River on most maps. Its type locality lies only a few miles from Stop 1 at Claybanks Preserve, a locality once commonly known as Hackberry Grove (Anderson and Furnish, 1987). These strata were termed the “Hackberry Stage” (or Hackberry beds) after this locality in several early reports, and the term “Rockford Shales” were also used (named after characteristic exposures a few miles to the east at Rockford). For a history of the nomenclature of these beds, the reader is referred to the classic early report on the “Hackberry Stage” by Fenton and Fenton (1924), as well as the excellent summary provided by Anderson and Furnish (1987). These strata have long been known as the “Lime Creek shales” at the Iowa Geological Survey following Calvin’s (1897) recommendation.

The Lime Creek Formation has been divided into three members, in ascending order, the Juniper Hill Shale Member, the Cerro Gordo Member, and the Owen Member (Fig. 1). The interval of the Juniper Hill Shale was excluded from the “Hackberry Stage” by the Fentons (1924) and erroneously assigned to the Sheffield Formation. Calvin (1897), however, had clearly included this shale-dominated within the Lime Creek Formation. The Juniper Hill is dominated by green-gray to gray calcareous shale, and is seemingly quite unfossiliferous on exposure. Nevertheless, the Juniper Hill Shale in an unweathered core penetration from the subsurface of southeastern Cerro Gordo County has yielded a relatively diverse brachiopod fauna (see Day, 1988, 1995, 1996) along with crinoid debris and other fossils.

The overlying Cerro Gordo Member consists of fossiliferous calcareous shales with intervals of nodular shaley limestone and beds of argillaceous limestone. This interval is one of the premier Paleozoic fossil-collecting units in the United States, and the member has yielded countless thousands (if not millions) of fossils to generations of fossil collectors. The Rockford Fossil and Prairie Area near the town of Rockford continues to attract fossil-collecting enthusiasts to scour the former brick and tile pits for the fossils that are continuously weathering out of the shaley slopes. This area was made accessible to the public in 1991 thanks to the Floyd County Conservation Board. The member is best known for its remarkable brachiopod fauna, with about 40 species identified (Day, 1995). Additional fossils include algal reproductive structures (charaphytes, spores), foraminifera (Cushman and Stainbrook, 1943), sponges, stromatoporoids (Stock, 1984), tabulate corals, rugose corals (solitary and colonial forms), bryozoans (cyclostomes, cryptostomes, trepostomes), bivalves (largely undescribed fauna, one of the most diverse Devonian bivalve faunas in North America), gastropods, cephalopods (nautiloids, the ammonoid *Manticoceras*, see Baker et al., 1986), tentaculites, calcareous worm tubes, annelid worm jaws (scolecodonts), echinoderms (crinoids, echinoids), ostracodes (Gibson, 1955), conodonts (Anderson, 1966), and fish material (placoderm, shark)(see also Fenton and Fenton, 1924; Wilson and McNamee, 1984, for further references on the remarkable Cerro Gordo fauna).

The upper member of the Lime Creek Formation, the Owen Member, is the least shaley interval of the formation, and is characterized by fossiliferous limestone, dolomitic limestone, and dolomite, interbedded with calcareous shale. Beds of oolitic limestone are known to occur in eastern Cerro Gordo County (Lynn, 1978). The Owen Member in the field trip area was subdivided into three intervals by Fenton and Fenton (1924): 1) a basal bed containing abundant branches of the digitate stromatoporoid *Amphipora* (called the “*Idiostroma* Zone” by *ibid.*); 2) a thick interval of fossiliferous dolomitic limestones and shales above (the “*Floydia* Zone” of *ibid.*; this characteristic Lime Creek gastropod was re-studied by

Eastern Cerro Gordo County  
Composite Section



**Figure 1.** General sequence of the Lime Creek Formation in the field trip area. Composite section largely adapted from Day (1995) and Anderson and Furnish (1987). General positions of the Bird Hill section (this stop) and the Rockford Fossil Area (visited on the October, 1995, GSI field trip) are shown. Lithologic symbols given in Figure 2.

Day, 1987, who noted its original spelling, *Floyda*, named after Floyd County); and 3) an upper interval characterized by an abundance of corals and stromatoporoids (the so-called “*Acervularia* [=*Hexagonaria*] Zone” of Fenton and Fenton, 1924; see Stock, 1984, for a listing of stromatoporoids from this interval). These latter two intervals likely share a partial lateral facies relationship across the outcrop belt of Cerro Gordo, Franklin, and Butler counties.

### ***Lime Creek Deposition***

The classic area of Lime Creek exposure in Floyd and Cerro Gordo counties marks an interesting transitional belt between coeval carbonate-dominated facies to the west (subsurface) and shale-dominated facies to the southeast. This classic area lies in the outer portions of a broad carbonate-dominated inner-shelf environment, where it interfingers with more offshore shale facies along the marginal region of this inner shelf (Witzke, 1987; Witzke and Bunker, 1996). Benthic fossils become increasingly rarer in an offshore direction, probably due to bottom oxygen stresses across the middle shelf region. Seaway depths were sufficient to maintain a stratified water column across the middle shelf area of southeastern Iowa, typified by a thin interval of dysoxic to anoxic shale facies of the coeval Sweetland Creek Shale in that area. By contrast, the Lime Creek Formation of northern and western Iowa includes carbonate facies deposited in oxygenated shallower-water settings. The Cerro Gordo and Owen members of the Lime Creek Formation in the field trip area, with their rich and diverse benthic faunas, must have been deposited in hospitable well-oxygenated environments.

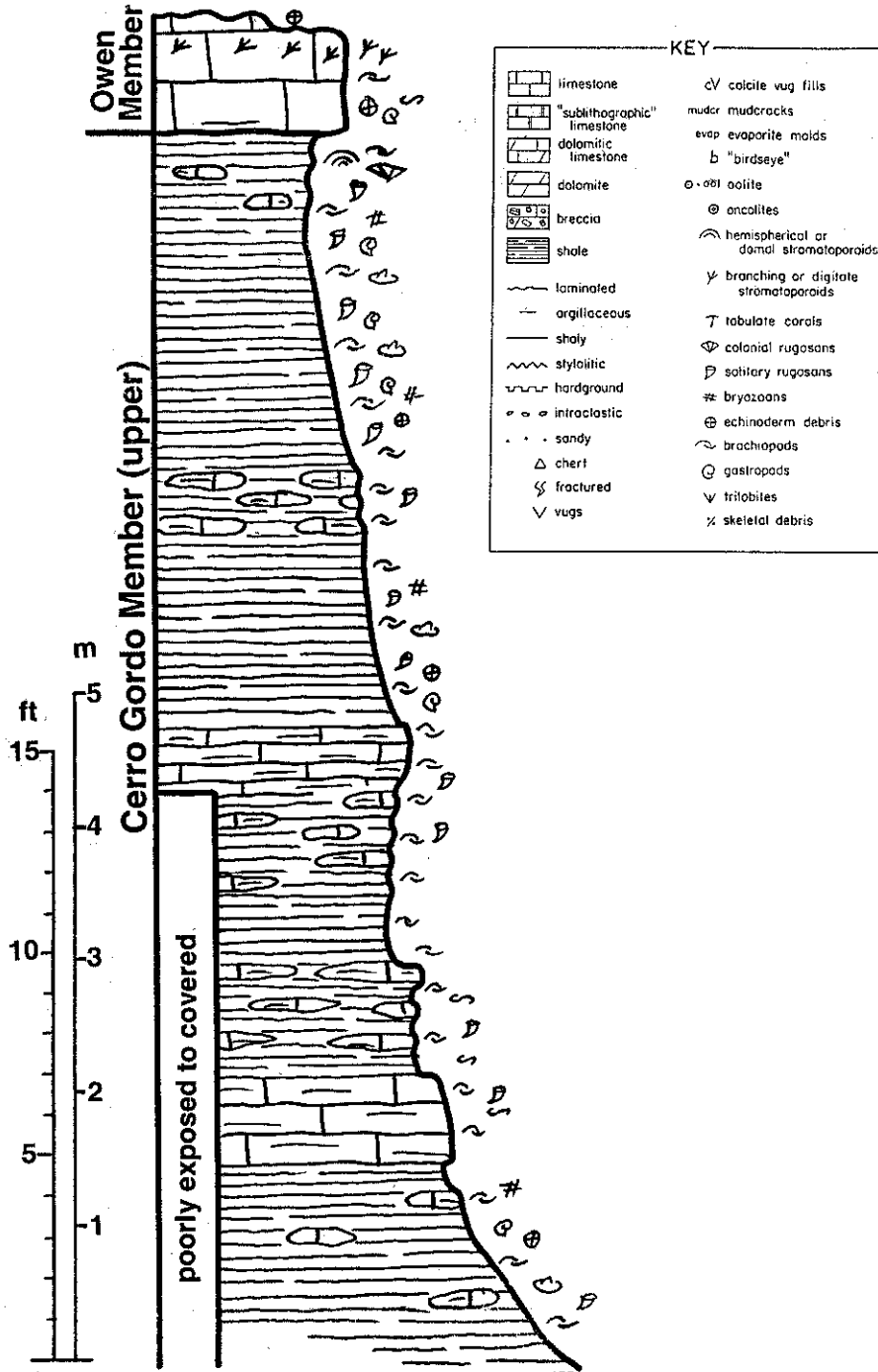
The Lime Creek Formation records a transgressive-regressive (deepening-shallowing) cycle of deposition. The shallowest facies in the field trip area are seen in the Owen Member, which includes oolitic and biosromal units. The deepest depositional environment of the sequence is represented in the Juniper Hill Shale, which includes dysoxic to oxic shale facies deposited when low-oxygen waters impinged along the margins of the inner shelf. A basal transgressive lag of phosphatic clasts and fish bone is found at its base. The Cerro Gordo Member represents an intermediate facies tract, not quite shallow enough for the development of stromatoporoid-rich and oolitic facies. The Lime Creek transgressive-regressive cycle is well displayed farther onto the inner shelf in the subsurface of central and western Iowa. There the formation records, in ascending order, a shallowing-upward sequence: 1) lower open-marine fossiliferous limestones, 2) a middle interval rich in stromatoporoid biostromes (similar to the upper Owen Mbr), and 3) an upper peritidal to supratidal facies, evaporitic in part (Witzke and Bunker, 1996). This latter facies is not seen in the type Lime Creek area, and was deposited in shallow restricted-marine to mudflat environments.

The Lime Creek depositional cycle was initiated as seas encroached across the continental interior during the late Frasnian following a prolonged period of erosion across Iowa. The basal erosional unconformity is developed on the upper Shell Rock Formation in the type Lime Creek area, but erosion locally truncated lower units of the Cedar Valley Group farther to the southeast. Likewise, a period of subaerial exposure and erosion followed Lime Creek deposition in Iowa, and deposition did not resume in northern Iowa until much later in the Late Devonian (mid Famennian shales of the Sheffield Fm.).

### ***The Exposure at Bird Hill***

The section at Bird Hill forms one of the primary reference sections of the Lime Creek Formation, exposing the upper part of the Cerro Gordo Member and the basal part of the overlying Owen Member (Figs. 1, 2). It is currently designated as a State Preserve, acknowledging its geologic significance. The sequence at the “Bird Hill locality” was described by Fenton and Fenton (1924, p. 13). Additional valuable descriptive information on this locality can be found in Belanski (1931), Anderson (1984), and Anderson and Furnish (1987). The Bird Hill exposure of Lime Creek strata is now considerably overgrown and covered compared to the early part of the century. Nevertheless, it remains an instructive and valuable exposure, although not nearly as well displayed as Lime Creek strata at the Rockford Fossil area or

**BIRD HILL EXPOSURE**  
 SW SE SE sec. 13, T95N, R19W,  
 Cerro Gordo Co., Iowa



**Figure 2.** Graphic stratigraphic column for Bird Hill locality (Stop 1), upper Cerro Gordo Member and basal Owen Member of the Lime Creek Formation. Lower part of section is now poorly exposed. Section adapted from Fenton and Fenton (1924), Anderson (1984), and Anderson and Furnish (1987).

at Hackberry Grove (Claybanks Preserve). The lower part of the exposure is now poorly represented, but aspects of these lower strata, as well as common fossils, can be seen in the parking area below the road level. This interval includes fossiliferous argillaceous limestone beds, with conspicuous burrows, in part (the "Fucoid Faunule" of Fenton and Fenton, 1924).

The upper shales of the Cerro Gordo Member are still accessible in the roadside hill exposure below the cap of Owen limestone. These shales, with scattered nodular argillaceous limestones, are exceptionally fossiliferous, although because of heavy fossil collecting at this locality, the actual abundance of fossils may not be as clearly represented as one might hope. A variety of brachiopods are found in this interval (Day, 1995), especially atrypids (*Pseudoatrypa devoniana*, *Spinatrypa rockfordensis*) and spiriferids (*Cyrtospirifer whitneyi*), along with other common forms (e.g., *Schizophoria iowensis*, *Theodossia hunderfordi*, *Strophodonta thomasi*, *Douvillina arcuata*). Molds of large gastropods (especially *Floyda*) and bivalves (especially *Paracylas*) are common. Solitary rugose corals (especially "*Tabulophyllum*") are also quite common. In addition, bryozoans and echinoderm debris can be seen. The top of the interval has produced colonial rugose corals (*Pachyphyllum*) and stromatoporoids (see Fenton and Fenton, 1924).

About 2.5 feet of resistant limestone ledges of the basal Owen Member can be seen at the top of the exposure, commonly dislodged and scattered along the underlying shale slopes. These are fossiliferous limestones (biopelsparites) with an abundance of stromatoporoid twigs in the upper part (*Amphipora*). Burrows, crinoid debris, bivalves, gastropods, brachiopods, and microfossils are also noted (Lynn, 1978).

Please be courteous of your fellow field trip participants on the potentially slippery slopes. Questions about fossils and the stratigraphy can be addressed to the trip leaders.

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**DEVONIAN CARBONATE STRATA IN THE MASON CITY AREA  
STOP 2A: HOLNAM LIMESTONE QUARRY**

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*Introduction and Previous Stratigraphic Studies*

Limestone and dolomite resources in the Mason City area have long held economic importance, providing building stone, aggregate, lime, and cement resources to the region beginning in the 1800s (Calvin, 1897). These rocks belong to the Devonian System, which were originally deposited as lime sediments in subtropical shallow-marine and mudflat environments that covered large areas of the continental interior of North America about 374 million years ago.

The Devonian carbonate rocks in the Mason City area were originally assigned to the “Cedar Valley Limestone” by Calvin (1897), a formation widely exposed across eastern Iowa. Calvin distinguished these strata as the “Mason City Substage” within the Cedar Valley Limestone. Belanski (1927) later proposed the “Shellrock Stage” for the upper interval of these limestone strata (below the Juniper Hill Shale) exposed in portions of Floyd, Butler, Worth, and Cerro Gordo counties. Although Belanski’s detailed studies did not exhaustively describe the exposures in the Mason City area, he clearly included these upper strata within the “Shellrock Stage,” noting that the interval there “shows heavy dolomitization” (Belanski, 1927, p. 363, also p. 332) unlike correlative limestone-dominated strata to the east. Belanski (1927) separated the “Shellrock” interval from underlying strata which he labeled “Cedar Valley strata undivided.” He correctly noted that the faunas of the “Shellrock” did not correlate with (were younger than) any faunas of the Cedar Valley Limestone exposed farther to the south (Belanski, 1927, 1928). At the time of Belanski’s publications, most geologists did not consider the distinction between time- and rock-stratigraphy, and time-terms (stages) were used synonymously with rock-terms (formations). Subsequent usage translated Belanski’s “Shellrock Stage” into its present rock-stratigraphic equivalent, the Shell Rock Formation (Koch, 1970). Belanski’s (1927) three-part subdivision of Shell Rock strata included, in ascending order, the “Mason City Substage,” “Rock Grove Substage,” and “Nora Substage”; these intervals are now recognized as members within the Shell Rock Formation (Koch, 1970).

Kohls (1961) investigated Devonian strata in northern Iowa and southern Minnesota, and he assigned the thick interval of carbonate strata exposed in the Mason City area to the Shell Rock Formation. Anderson’s (1966) Devonian biostratigraphic studies in northern Iowa identified zonally significant conodonts from the Shell Rock Formation which indicated an early Late Devonian age (early Frasnian, Middle *asymmetricus* Zone). Koch’s (1967, 1970) detailed studies of the Shell Rock Formation remain a valuable reference for Devonian strata in north-central Iowa. He interpreted upper Shell Rock strata (Nora Member) to lie unconformably on the Coralville Member of the Cedar Valley Formation in quarries and exposures in the Mason City area. Belanski (1927) had earlier interpreted a southward overstepping of lower Shell Rock strata. Koch (1970) similarly interpreted a broad westward overstepping of Shell Rock strata into the Mason City area which excluded lower and middle Shell Rock strata (Mason City, Rock Grove members) from that area. He restricted Shell Rock strata in the Mason City area to a fossiliferous limestone (stromatoporoid-rich) and dolomite interval at the top of the quarry sections which was assigned to the Nora Member. This interval was interpreted to overlie limestone and dolomite strata of the Coralville Member, Cedar Valley Formation.

Witzke and Bunker (1984) re-interpreted Devonian units in northern Iowa, and they initially used a deep rock-core penetration of the Devonian sequence at Mason City as a primary reference section for the region (Mason City core, stored at Iowa DNR-Geol. Survey Oakdale facility). They suggested that

the upper interval in the Mason City core (their "Unit E" of the Cedar Valley) represents a more dolomitic facies of the typical Shell Rock section exposed at Nora Springs (*ibid.*, p. 126-127). This interpretation differed from that of Koch (1970) in that it proposed that the Shell Rock Formation does not display westward overstep above a regionally incised surface, but is represented to the west by a different suite of facies. This interpretation is further supported by the stratigraphic relations outlined in this guidebook. Anderson (1984) summarized the varying interpretations of the stratigraphic sequence exposed at Mason City in his Tri-State Geological Field Conference Guidebook. That field trip visited the Lehigh Portland Cement Quarry northwest of Mason City, and the guidebook included detailed stratigraphic sections for that quarry as well as one of the Northwestern States Portland Cement quarries (now owned by Holnam).

Witzke, Bunker, and Rogers (1988) presented a revision of the Devonian stratigraphy in the Iowa area at the Second International Symposium on the Devonian System in Calgary, and this compilation included a discussion of the Shell Rock Formation. The Cedar Valley Limestone was elevated to group status, the "Cedar Valley Group," to encompass, in ascending order, the Little Cedar, Coralville, Lithograph City, and Shell Rock formations. Each formation characterizes a large-scale transgressive-regressive cycle of deposition, each bounded by disconformities. Witzke and Bunker recognized the Shell Rock Formation over a much broader geographic extent than proposed by earlier workers, and they extended its distribution into the subsurface of central and western Iowa (where minor evaporites occur). Witzke et al. (1988) included facies within the Shell Rock, including peritidal/mudflat facies of limestone and dolomite, that had been associated with "Coralville" strata in previous reports. They also slightly raised the position of the basal contact of the Shell Rock Formation from that of Belanski (1927) and Koch (1970) to coincide with the depositional boundary separating the final regressive phases of the Lithograph City cycle (peritidal/mudflat facies with evidence of subaerial exposure) from basal transgressive strata of the Shell Rock cycle (lower Mason City fossiliferous limestones, biostromal in part). The inclusion of the Shell Rock Formation within the Cedar Valley Limestone (Group) differed from the stratigraphic schemes of Belanski (1927) and Koch (1970) who separated Shell Rock and Cedar Valley strata. However, as noted above, Calvin (1897) had earlier included these strata within the Cedar Valley, and he described clear lithologic similarities between his "Mason City substage" of Cerro Gordo County and Cedar Valley strata elsewhere in eastern Iowa. The general similarity of carbonate lithologies in the Shell Rock Formation with underlying carbonate strata of the Cedar Valley Group, as well as the hydrologic continuity of groundwater movement through these strata in northern Iowa (Witzke and Bunker, 1984), makes inclusion of the Shell Rock within the Cedar Valley Group a meaningful lithostratigraphic grouping.

### ***Paleontology of the Shell Rock Formation***

The Shell Rock Formation is richly fossiliferous, and its fossils have been the focus of several studies. As noted above, Anderson (1966) reported on conodonts (tooth-like microfossils) from the formation, establishing its age as early Late Devonian. Belanski's (1928) report on the fossils of the Shell Rock remains an impressive record of a fauna he had carefully collected primarily from exposures in western Floyd and eastern Cerro Gordo counties. That report described colonial rugose corals, echinoderms (crinoids, echinoids), and numerous brachiopods, but large parts of Belanski's exceptional collection (now housed at the University of Iowa, Dept. Geology) remain undescribed, especially the mollusks (bivalves, gastropods, nautiloids, rostroconchs) and corals (tabulates and solitary rugosans). Koch and Strimple (1968) described a remarkable echinoderm fauna attached to a hardground surface in the Mason City Member, dominated by encrusting edrioasteroids and perfectly-preserved rhombiferan cystoids. Day (1988) summarized and updated the diverse brachiopod fauna (32 species) of the Shell Rock Formation, based to a large extent on Belanski's collections. He used these faunas to define the *Tenticospirifer shellrockensis* and *Strophodonta cicatricosa* Zones (Day, 1988, 1996). Day continues work on the



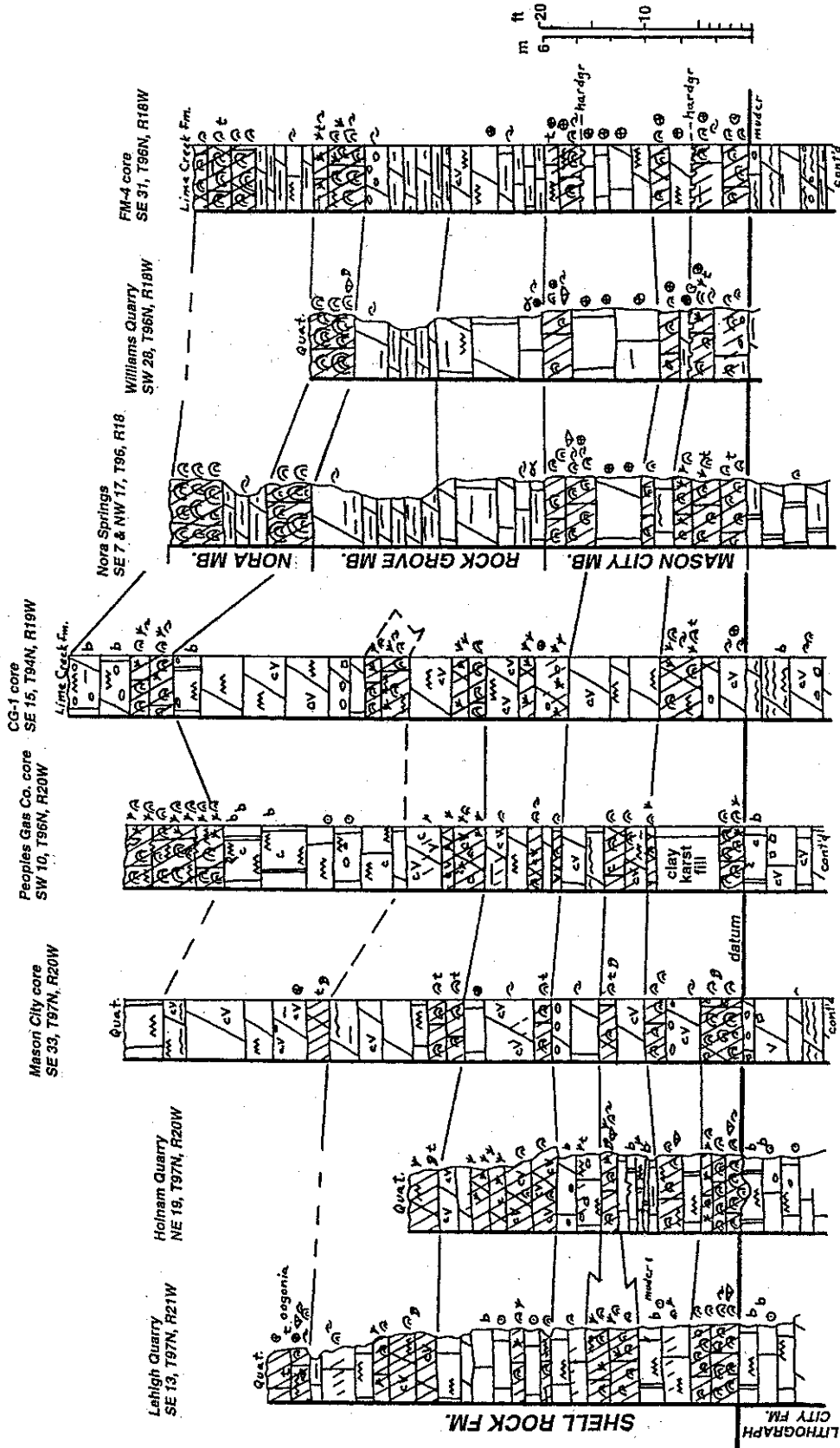


Figure 1. Stratigraphic sections and proposed correlations of upper Cedar Valley Group strata in Cerro Gordo and Floyd counties, Iowa. The four graphic sections on the left are from the Mason City area, including core penetrations and quarry exposures. The CG-1 core is from southeastern Cerro Gordo County, and the remaining sections are from Floyd County. Lehigh Quarry section is primarily adapted from Koch (1970) and Anderson (1984); Nora Springs and Williams Quarry sections are largely derived from Koch (1970). All core sections are stored at the Iowa DNR-Geological Survey Bureau (Oakdale facility). Datum is the interpreted top of the Lithograph City Fm. For symbols and abbreviations see Figure for Stop 1 (except that circle with central dot here represents occurrences of calcispheres). Diagonal cross-ruling is shown to accentuate intervals bearing stromatoloids and/or corals (most are biostromes).

brachiopod faunas of the Shell Rock (and other units of the Iowa Devonian), with upcoming publications in the near future (including a paper on Shell Rock atrypids, 1998, *Acta Paleontologica Polica*, v. 43, in press). Additional fossils in the Shell Rock Formation include ostracodes, spirorbids (worm tubes), conularids, calcareous algae, calcispheres, charophytes, and fish debris (Koch, 1970).

Stromatoporoids are the most conspicuous fossils of the Shell Rock Formation, and domal to sub-spherical and stick-like branching forms commonly form dense accumulations in some beds. These accumulations are termed “biostromes,” reef-like tabular bodies of coralline fossils. These extinct colonial organisms possessed a robust calcareous skeleton displaying a microstructure of horizontal laminae and vertical pillars. The biological affinities of stromatoporoids has been the subject of long-standing debate. Stromatoporoids have been variably considered over the years to represent sponges, hydrozoans, encrusting foraminifera, algae, or a distinct phylum of their own (Phylum Stromatoporoidea). The discovery of living stromatoporoid-like creatures in the modern tropical ocean, which have been assigned to the Class Sclerospongia within the sponges (Phylum Porifera), provides support that the ancient stromatoporoids are best considered to be highly-skeletalized sponges (Phylum Porifera), as now regarded by most paleontologists. Stromatoporoids recovered from strata now assigned to the Shell Rock Formation were first described by Hall and Whitfield (1873). The diverse fauna of stromatoporoids in the Shell Rock Formation has been summarized in several reports by Carl Stock (1982, 1984a, 1984b), and the stromatoporoid fauna of the underlying Lithograph City Formation has recently been studied by Smith (1994), a student of Stock. Stock’s Shell Rock studies were largely limited to strata in western Floyd County, and the abundant stromatoporoid fauna displayed in the Mason City area has not been investigated. A single stromatoporoid was described from Mason City in the last century (Quenstedt, 1876; see reference in Stock, 1984a), but the remainder of the fauna there awaits further study.

### *The Upper Cedar Valley Group in the Mason City Area*

Upper Cedar Valley strata are well represented in a number of quarries, natural exposures, and bed-rock cores in the Mason City area. A series of stratigraphic sections in the area provides the basis for a re-assessment of the stratigraphy in the Mason City cement quarries (Fig. 1). The interpretation presented here assigns most of the exposed strata in the Mason City area to the Shell Rock Formation. The lower exposed interval in the area is assigned to the upper part of the Lithograph City Formation.

The Lithograph City Formation was named by Witzke, Bunker, and Rogers (1988) for strata in northern Iowa previously assigned to the upper “Coralville” Member. The upper strata of the formation in the Mason City area, which are assigned to the Idlewild Member, encompass the lower cement ledges in the active cement quarries. These strata include peritidal/mudflat facies of dense “sublithographic” limestone and dolomitic limestone. The “sublithographic” label refers to its dense extremely fine-grained character, similar to limestones that were once widely used for lithographic engraving. Stylolites are common in the interval. These beds are, in part, intraclastic to brecciated, faintly laminated, “birdseye”-bearing, or pelletal. The interval is dolomitic to varying degrees, displaying lateral facies variations over relatively short distances. “Floating” dolomite rhombs are scattered to abundant in the dense dolomitic limestones, although these rhombs are commonly calcitized (later replacement by calcite).

Although the upper Lithograph City Formation is not noticeably fossiliferous in the Mason City area, scattered small branching stromatoporoids are present in a few beds, and calcispheres are not uncommon. Calcispheres are tiny calcitic spheres a fraction of a millimeter in diameter (probably reproductive bodies of calcareous algae) that are found in many peritidal and shallow-marine facies of the Cedar Valley Group.

These upper strata of the Idlewild Member display evidence of subaerial exposure of mudflat facies during their deposition, especially in the uppermost beds immediately below the base of the Shell Rock Formation. In particular, an abundance of “calcite spots” (small calcite void fills) and “birdseye” structures in these beds are characteristic features of emergent mudflats. The so-called “birdseye” voids are small calcite-filled voids generally about 0.5 to 2 mm in diameter; these features may interconnect into a

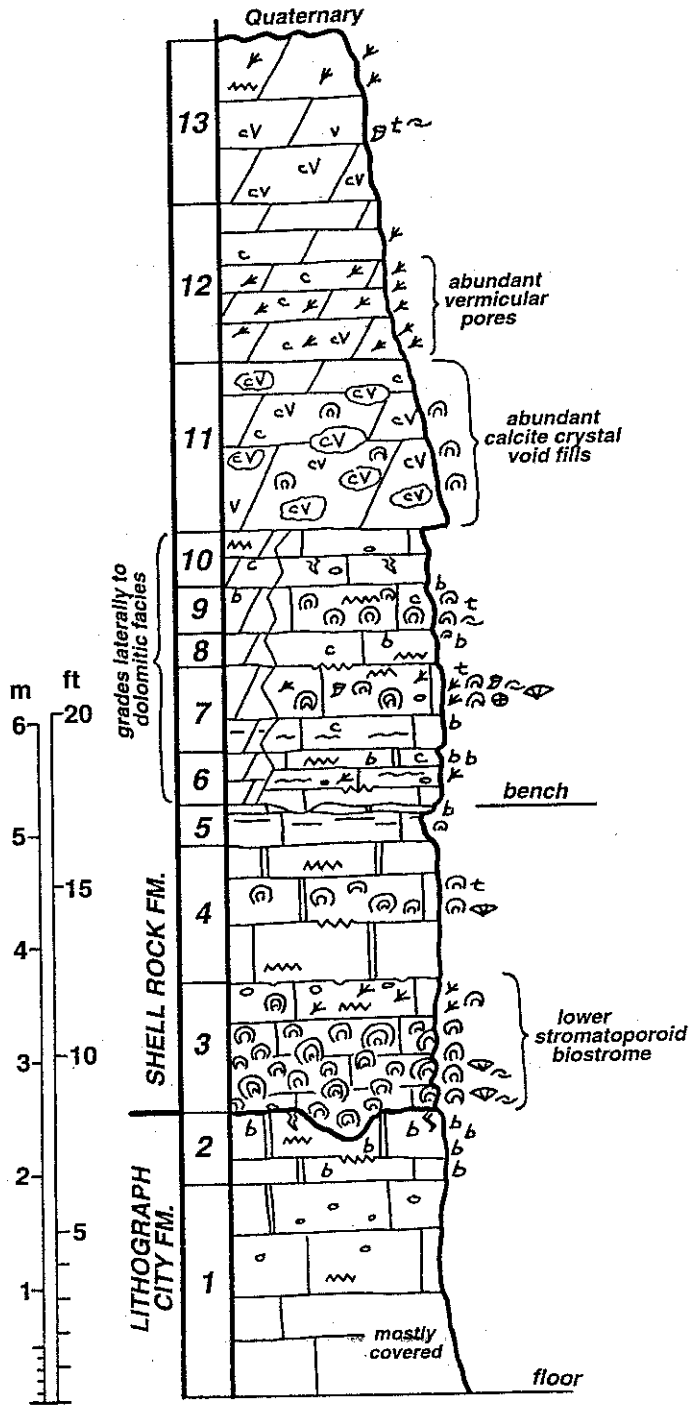
fenestral network. These features are known to form in modern mudflats by the decay of organic matter which releases small gas bubbles that become trapped in the enclosing sediments. Essentially, “birdseye” structures are fossil bubbles. In addition, discontinuous vertical fractures and mudcracks are known in the interval, and these indicate partial desiccation of exposed mudflat facies. The sequence of these strata indicates progressive shallowing of restricted nearshore and mudflat facies, culminating in subaerial exposure. Such a sequence marks the final regressive phase of sedimentation of a typical transgressive-regressive cycle of deposition in the Cedar Valley Group, and the top of this sequence in Mason City is used to delineate the top of the Lithograph City Formation. As seen in the Holnam Quarry on this field trip, some erosional relief is locally displayed on this surface, a common feature at formational contacts of the Cedar Valley Group in northern Iowa.

A transgression of fossiliferous shallow-marine facies is seen above this surface, which is interpreted to mark the base of the Shell Rock depositional cycle (Fig. 1). The basal unit in the Mason City area is a distinctive stromatoporoid biostrome containing packed concentrations of subspherical stromatoproids in a fossiliferous limestone matrix. Small broken branches of stick-like stromatoporoids also occur, especially in the upper part. Although stromatoporoids are clearly dominant, other fossils are also present which indicate a normal-marine sedimentary environment such as brachiopods (indeterminate forms), crinoid debris, small ramose tabulate corals, solitary rugose corals, and colonial rugose corals. The recognition of colonial rugose corals assignable to the genus *Pachyphyllum* at the Holnam Quarry is especially significant, as this genus is not known to occur below the Shell Rock Formation in Iowa (*P. websteri* was confined to the Mason City Member by Belanski, 1928). Its presence in these strata, therefore, does not support a correlation with the Coralville or Lithograph City formations as previously assigned, but is consistent with inclusion in the lower Shell Rock Formation. This biostromal interval likely correlates with similar stromatoporoid-bearing limestone beds in the lower Mason City Member in western Floyd County (Fig. 1). Higher stratigraphic levels in Mason City also contain *Pachyphyllum* (e.g., see unit descriptions for Holnam Quarry), further supporting assignment of these strata to the Shell Rock Formation.

Unlike lower Shell Rock strata exposed east of Mason City, interbedded peritidal facies occur in the Mason City area (and westward into the subsurface of central and western Iowa) which indicate generally shallower depositional conditions and the progradation of mudflat environments in that area. The presence of “birdseye” bearing sublithographic limestones at Mason City indicates episodic subaerial exposure of the mudflat environments. In general, the interbedding of peritidal and shallow-marine facies records a series of small-scale depositional cycles which mark the waxing and waning of shorelines across northern and central Iowa. The classic Shell Rock sections near Nora Springs do not show such peritidal facies, and that area must have lain in a slightly more offshore setting during Shell Rock deposition. Nevertheless, a general similarity of the positions of biostromal and stromatoporoid-bearing units is apparent between sections in Cerro Gordo and Floyd counties (Fig. 1), and it is tempting to suggest that minor relative sea-level fluctuations may have influenced these facies patterns. As seen in all Cedar Valley cycles, the inner-shelf facies of Shell Rock strata in northern Iowa form a complex mosaic of peritidal, restricted-marine, and shallow-marine units.

The Shell Rock Formation in the Mason City area cannot be readily divisible into the three members which had been previously defined in the type area of the formation (as earlier recognized by Belanski, 1927), and, as such, the formation is currently left undivided in the Mason City area. In particular, the argillaceous dolomitic strata of the Rock Grove Member, which lack stromatoporoid-rich units, is not clearly identifiable at Mason City, where equivalent strata apparently encompass stromatoporoid-bearing units as well as intervals of peritidal carbonates, dolomitic in part (Fig. 1). The upper half of the Shell Rock Formation at Mason City, however, is dominated by dolomites and dolomitic limestones, as it is in the type area farther to the east. Lateral variation between stratigraphically-equivalent limestone and dolomite facies occurs over short distances in the Mason City area, even within the confines of a single quarry (as seen at Stop 2). Upper Shell Rock strata in the Mason City area, which are probably equivalent to part of the upper Rock Grove Member to the east, are observed to vary between peritidal

**Holnam Limestone Quarry**  
 NE sec. 19, T97N, R20W, Cerro Gordo Co.



**Figure 2.** Graphic representation of the stratigraphic section exposed in the Holnam Quarry near Mason City, Iowa. Unit numbers correspond to accompanying written descriptive log. Symbols used are identified in the key to the Figure for Stop 1.

sublithographic limestones (with “birdseye” structures upward) and vuggy dolomites (laminated upward)(see Peoples Gas and Mason City cores, Fig. 1).

The upper member of the Shell Rock Formation in the Nora Springs area, the Nora Member, is marked by densely-packed stromatoporoid biostromes unconformably below the shales of the Lime Creek Formation. Similar stromatoporoid biostromes occupy the same stratigraphic position in the Mason City area (e.g., People Gas Co. core, Fig. 1), and these most likely correlate with the Nora Member. As seen in the CG-1 core of southeastern Cerro Gordo County, the upper Nora interval includes “birdseye” and intraclastic dolomitic limestones, which marks the final shallowing phase of the Shell Rock depositional cycle. Koch (1970) had earlier assigned an interval of coral-bearing strata at the top of the cement quarries in the Mason City area to the Nora Member, although these strata probably occur at a slightly lower stratigraphic level than the Nora equivalents recognized herein. This fossiliferous unit (e.g., top of Lehigh Quarry section, Fig. 1) contains a relatively diverse marine assemblage including brachiopods (spiriferids, atrypids), crinoid debris, gastropods, nautiloids, subspherical stromatoporoids, corals (auloporids, colonial rugosans), and charophyte oogonia (small spherical calcitic reproductive organs of certain green algae)(Koch, 1970; Anderson, 1984). The unit is apparently replaced laterally by a coral-bearing dolomite unit in the Mason City core (Fig. 1).

### *Field Trip Stop at the Holnam Quarry*

This stop, here labeled the Holnam Quarry, is one of many expansive quarries north of Mason City where ongoing quarrying operations are mining limestone for cement manufacture. PLEASE BE CAUTIOUS ALONG THE QUARRY WALLS, AND FOLLOW ALL INSTRUCTIONS OF THE TRIP LEADERS AND COMPANY PERSONNEL FOR YOUR SAFETY. HARD HATS ARE REQUIRED.



**Figure 3.** Abundant calcite-lined vugs (unit 11) and adjacent strata in upper quarry face, Holnam Quarry. Scale is one Witzke height-unit (1.94 m).

This quarry exposes representative units of the upper Lithograph City and lower Shell Rock formations (Fig. 2) which can be seen at numerous localities in the Mason City area (Fig. 2). Approximately the lower 25 feet (7 m) of the section is quarried for cement manufacture.

Field trip participants are encouraged to examine several aspects of the stratigraphic sequence at the Holnam Quarry. The lower quarry ledges (units 1, 2) are dominated by dense limestones which display common “birdseye” fenestrae below the contact with the lowest stromatoporoid biostrome. These strata are here assigned to the Lithograph City Formation. The contact with overlying unit locally displays erosional relief of up to 30 cm along the quarry walls.

The lower stromatoporoid biostrome (unit 3) is used here to mark the base of the Shell Rock Formation. This unit is a remarkable accumulation dominated by subspherical stromatoporoids. Although this unit is a limestone, it is riddled with green-gray clay karst fills to varying degrees throughout much of the quarry. The clay fills in fractures and void spaces between the bulbous stromatoporoids, locally forming considerable masses of clay. Green-gray clay fills are common in Silurian and Devonian strata across much of eastern Iowa, and most, if not all, of these clays represent Upper Devonian clays derived from the Lime Creek Formation. An episode of karst development was widespread across eastern Iowa following Cedar Valley deposition, and the karstic openings were apparently infilled when regional deposition resumed in the late Frasnian (Lime Creek Fm.). Additional green-gray clay fills can be seen at other stratigraphic positions within the quarry, but it is particularly noteworthy in unit 3.

Overlying strata (units 4-10) include a complex of interbedded stromatoporoid-bearing intervals and dense “sublithographic” limestones, “birdseye”-bearing in part (see unit descriptions for more detail). These units record an interfingering of shallow-marine and peritidal (mudflat) facies in the lower Shell Rock Formation. Such facies relations are not seen at the classic Shell Rock sections eastward towards Nora Springs. The upper part of this interval (units 6-10) is locally represented by calcitic dolomite within the quarry. These dolomitic facies do not faithfully preserve original depositional fabrics, but they commonly show strange irregular mottlings of darker or lighter colored domains within the dense matrix. Such mottlings are common in many dolomitic intervals of the Cedar Valley Group in northern Iowa, although their origin remains unclear and unstudied.

The upper part of the quarried interval (units 11-13) at the Holnam Quarry consists of dolomite, variably calcitic, and the interval commonly shows vugs and void spaces which are lined or filled with calcite. The lower part (unit 11) displays a remarkable abundance of calcite-crystal lined vugs and void spaces, some of which appear to be molds of subspherical stromatoporoids (which are also recognized as calcitic masses within the dolomite matrix). This calcite-rich unit is found at other localities in the Mason City area, but none displaying such an abundance as here at the Holnam Quarry (see Fig. 3 for photo of this interval). The calcite crystals are commonly large and well-preserved, including dogtooth spar, rhombic crystals, and tabular crystal forms; pyrite may be associated. The upper ledges of the quarry (units 11-12) show notably fewer calcite fills, but “vermicular” (worm-like) pores are conspicuous in part. Similar pores were described by Anderson (1984) in a nearby quarry, and he reasonably interpreted them to be pores of twig-like branches of stromatoporoids. Additional fossils are preserved as molds in the dolomite, including small corals and brachiopods (unit 13).

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**Holnam Limestone Quarry**

NE sec. 19, T97N, R20W, Cerro Gordo Co.

section described by B. Witzke, R. Anderson, 3/25, 1998

**UPPER DEVONIAN**

**UPPER CEDAR VALLEY GROUP**

**SHELL ROCK FORMATION (undifferentiated)**

- Unit 13.** Dolomite, calcitic, in 2 to 3 beds, light brown-gray, scattered stylolites, top 50 cm weathered and broken; lower 75 cm with abundant calcite void and vug fills (1-8 cm), moldic porosity, scattered fossil molds 55-70 cm above base include atrypid brachiopods, small horn corals, small favositids; top 50 cm with scattered vermicular porosity (probably branching stromatoporoids). Thickness: 1.4 m (4.6 ft).
- Unit 12.** Dolomite, calcitic, m. brown-gray, f-m crystalline, in beds 10 to 30 cm thick; lower 35 cm with scattered calcite void and vug fills (up to 10 cm), less so than underlying unit; abundant calcitic patches; lower 90 cm with common vermicular pores (tubular pores 1-2 mm diameter, 0.5-3 mm long), probably stromatoporoid branches; upper 50 cm denser, porosity decreases upward, common irregular gray mottles. Thickness 1.4 m (4.6 ft).
- Unit 11.** Dolomite, calcitic, light to m. brown-gray to m. dark gray, in thick beds, vf- m crystalline, scattered stylolites, irregular darker mottlings scattered to common; local overhanging ledge at base, generally recessive upward; abundant calcite vug fills and linings, vugs <1 to 40 cm, calcite linings include crystals of dogtooth and rhombic spar, some tabular forms, unit varies from 10 to 40% calcite vugs; areas of fewer vugs have calcitic domains ranging from 3-15 cm, most of which appear to be massive to subspherical stromatoporoids, some better preserved stromatoporoids noted. Thickness: 1.5 m (4.9 ft).
- Unit 10.** Limestone, light to m. brown-gray, dense, slightly recessive, xf crystalline with coarse crystalline calcite mottles (especially in lower half); abundant calcite spots, partly as lighter-colored fenestral fills; scattered dark mottles, some are rounded intraclasts (1-5 cm); upper surface slightly irregular. Thickness: 48 cm (1.6 ft).
- Unit 9.** Limestone, v. light brown, dense, scattered stylolites, scattered calcite spots and discontinuous vertical calcite fractures upward; slightly recessive upward; common subspherical stromatoporoids (1-15 cm diameter), scattered indeterminate brachiopods, rare thamnoporid coral (2 cm). Thickness: 41 cm (1.3 ft).
- Unit 8.** Limestone, v. light brown, dense, scattered stylolites, common calcite spots, scattered calcite-filled "birdseye" voids (1-2 mm), calcispheres; scattered subspherical stromatoporoids at top. Thickness: 30 cm (1.0 ft).
- Unit 7.** Limestone, pale to v. light brown-gray, dense, forms single bed; lower 30 cm is light gray mottled, scattered calcite spots and void fills, very faint horizontal laminations in part, possible scattered "birdseye" near top; upper 45 cm is a fossiliferous biostrome, slightly dolomitic in upper 30 cm, scattered to common subspherical to hemispherical stromatoporoids (2-20 cm diameter), scattered small stromatoporoid branches (*Amphipora*), scattered indeterminate brachiopods, scattered crinoid debris, solitary rugose corals in middle (1-3 cm diameter), rare colonial rugose corals (*Pachyphyllum*, 3 cm), rare ramose favositid corals, rare rostroconch mollusks (*Conocardium*), swarm of stylolites at top, prominent bedding break at top. Thickness: 75 cm (2.5 ft).



**Unit 6.** Limestone, pale brown-gray to light brown, in three beds; lower bed (13 cm, variable thickness on underlying surface), light brown with irregular gray mottles, slightly dolomitic, fine-grained packstone; second bed (17 cm), dense limestone, irregular horizontal laminations in part, stylolites, scattered to common fine-grained intraclasts, scattered stromatoporoid branches (1-2 mm diameter, *Amphipora*); top bed (19 cm), pale brown-gray, dense, xf-SL (“sublithographic”), stylolites, common calcite spots and “birdseye” fenestrae. Thickness: 49 cm (1.6 ft), locally thickens up to 5 cm at base.

**Units 6-10** undifferentiated. Limestone-dominated facies (described above) are replaced laterally within the quarry walls by dolomite-dominated facies. Dolomite, calcitic, light gray to light m. brown-gray, xf-vf and vf-m crystalline, in beds 10 to 40 cm thick, irregular to elongate lighter-colored mottles through most of interval; 55-66 cm below top of interval includes irregular 1-2 mm calcite-filled pores (probably “birdseye”); top 35 cm includes scattered pores and calcite spots, stylolites, calcite void fills (2-3 cm). Thickness: 2.46 m (8.0 ft).

**Unit 5.** Limestone; lower 25 cm is dark gray, slightly dolomitic, argillaceous to shaly upward, locally with scattered small stromatoporoids (2 cm); upper 6-10 cm, limestone, dense, very light brown, xf-SL (“sublithographic”), scattered to common “birdseye” fenestrae, thin shaly parting at top. Thickness: maximum 35 cm (1.1 ft); irregular eroded upper surface with up to 15 cm of relief, upper “birdseye” limestone locally absent.

**Unit 4.** Limestone, light brown, xf crystalline to SL (“sublithographic”), scattered stylolites, unit forms resistant ledges; lower 52 cm with irregular gray mottles, stylolitic surface at top; middle interval (52-90 cm above base), fossiliferous to biostromal, scattered subspherical stromatoporoids (2-15 cm diameter), scattered small stromatoporoid branches (1 mm diameter, *Amphipora*), rare colonial rugose corals (*Pachyphyllum*, 5 cm), rare ramose favositid corals (3 cm); upper 30 cm, becomes more “sublithographic” upward. Thickness: 1.2 m (3.9 ft).

**Unit 3.** Limestone, light to medium brown gray to gray, locally dark gray with light to m. gray mottling, minor calcite void fills, dense but commonly weathered to nodular lumpy limestone with green-gray clay fills [these are clay karst fills along solutional bedding surfaces and fractures, most likely green-gray clays of the Lime Creek Formation; these karst fills are locally seen in most units displayed within the quarry, but are particularly common in unit 3]; lower 83 cm is a stromatoporoid biostrome, abundant subspherical stromatoporoids (2-25 cm diameter), packed in part, scattered indeterminate brachiopods in lower half, rare colonial rugose corals in lower part (*Pachyphyllum*, 2-6 cm); scattered intraclasts at base; upper 34 cm of unit is denser with gray mottles, scattered stylolites, less fossiliferous than below, scattered subspherical stromatoporoids smaller than below (2-4 cm), scattered to common stromatoporoid branches (2-5 mm diameter, *Amphipora*); intraclasts near top (1-8 cm), some with dark gray margins; upper surface slightly irregular, dark gray margins (possible hardground). Thickness: 1.17 m (3.8 ft); basal contact irregular, locally incised up to 30 cm into underlying unit (i.e., unit 3 locally to 1.47 m thick).

## LITHOGRAPH CITY FORMATION

**Unit 2.** Limestone, pale brown-gray to light orange-gray, dense, dominantly SL (“sublithographic”), part xf crystalline, prominent stylolitic surfaces; lower 20 cm with common calcite spots and “birdseye” structures (1-3 mm diameter), “birdseye” coalesce into

subhorizontal fenestrae (1-15 mm across), scattered calcite void fills (to 20 cm); upper 40 cm, calcite spots, scattered to common “birdseye” structures (0.5-3 mm diameter); top 10-15 cm xf crystalline, mottled to weathered, internal sediment fills; upper contact irregular, with common karstic fills of green-gray clay. Thickness: 60 cm (2.0 ft), locally thinner where incised by unit 3 (see above).

**Unit 1.** Limestone, pale brown-gray to light orange gray, xf-m crystalline to SL (“sublithographic”), scattered to common calcispheres; common m-c rhombic crystal inclusions (calcitized dolomite rhombs), scattered stylolites, part with irregular light gray mottles, includes some fine intraclastic packstone; interval is mostly covered at base of quarry walls. Measured thickness from quarry floor varies from 1.0-2.0 m (3.3-6.5 ft); thicker at quarry sump.

## **STOP 2B: PORTLAND CEMENT PRODUCTION AT THE HOLNAM INC. MASON CITY PLANT**

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with information provided by  
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Holnam Inc.

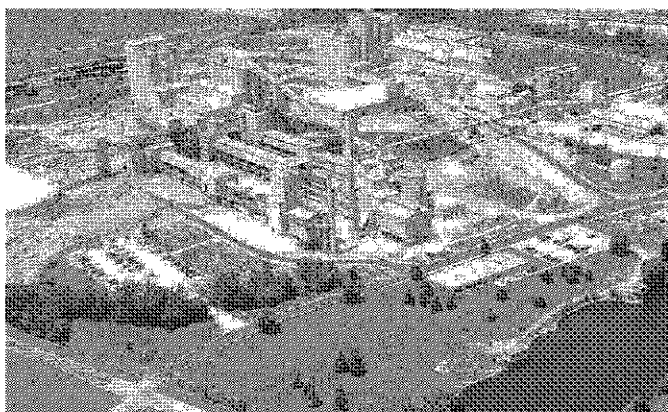
### **INTRODUCTION**

Portland cement is an extremely fine powder manufactured from a number of materials common to the Iowa landscape. When combined with coarse aggregate (gravel or crushed stone), fine aggregate (generally sand), and water it hardens into a rock-like mass called concrete, “easily the most widely used building material on earth,” Portland Cement Association (1992). Natural cements have been used since the time of the Roman Empire, but the origin of Portland cement goes back only to 1824. Portland cement was invented and named by Joseph Aspdin, an English stonemason who first produced the material by heating powdered limestone and clay in a small furnace, creating a hydraulic cement (cement that would harden with the addition of water.) When his new cement hardened it resembled a highly prized building stone that was quarried off the English coast on the Isle of Portland, hence the name “Portland Cement”. Since its invention, the formulation of Portland cement has been modified many times to suit specific needs or the local materials available. However, it is essentially made up of materials containing oxides of calcium (limestone, dolomite, marl, or chalk), silicon (clay, shale, bauxite), aluminum, and iron. The calcium can come from limestone, dolomite, marl, or chalk; the silicon, aluminum, and iron can come from clay, shale, or sand. Other materials that are used locally include iron ore, bauxite, seashells, furnace slag, and fly ash. The raw products are mixed together in a specific proportion, ground into a silt consistency, and then fired in a furnace or kiln to produce a clinker. The clinker is ground to a fine powder to produce the final product.

### **CEMENT INDUSTRY IN MASON CITY**

The potential importance of a limestone quarrying industry in the Mason City area was recognized as early as 1897 by State Geologist Samuel Calvin who wrote the following:

*“The quarry industry of Cerro Gordo county is yet in its infancy. . . . (At all Mason City area limestone) exposures the admirable quality of the stone with respect to its power of resisting the weather, is well demonstrated. In the second place, Mason City is situated at the border of an enormous quarryless area whose supplies of building stone must all be imported. No situation could be better chosen for commanding the markets of the great plains stretching away for hundreds of miles to the northwest, west and southwest. Here is an area growing annually in*



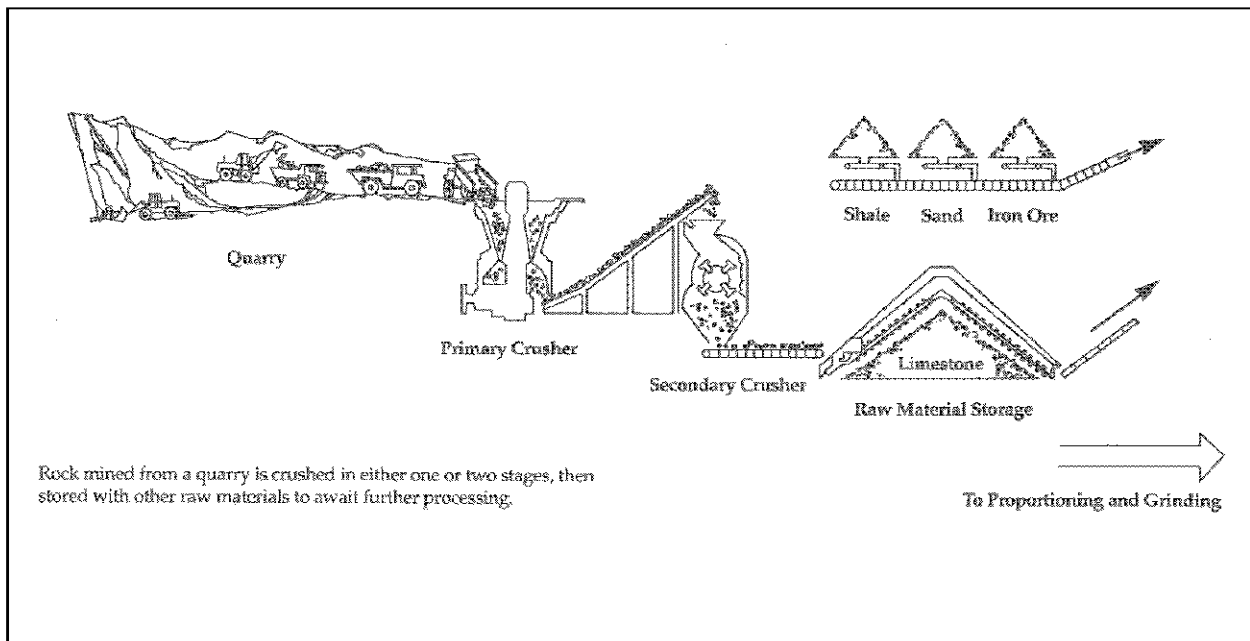
**Figure 1:** Aerial Photograph of the Holnam Inc. Mason City cement plant. Photo courtesy of Holnam Inc.

*wealth and population, but an area in which the indurated rocks are deeply buried under a thick mantle of drift. The facility with which stone may be quarried along Lime creek and its tributaries, coupled with the excellence of the product, should, therefore, enable Mason City to get an ever increasing share of the building stone trade in the vast stoneless empire to which this city is practically the gateway.” (Calvin, 1897, p. 187).*

Although Portland Cement was not yet produced in the area, the limestone of the area was being burned to produce lime by A.T. Lein and Brother in the late 1800s in Mason City. Calvin (1897, p. 187) noted:

*“The Cedar Valley stage is capable of furnishing indefinite supplies of lime-burning rock, some of which produces a very high grade of lime.”*

The lime was burned in the Champion draw kiln, which burned 3 tons of coal for every 150 barrels of lime produced. The limestone units that were quarried and burned were the same units that are currently burned to make cement by Holnam Inc.



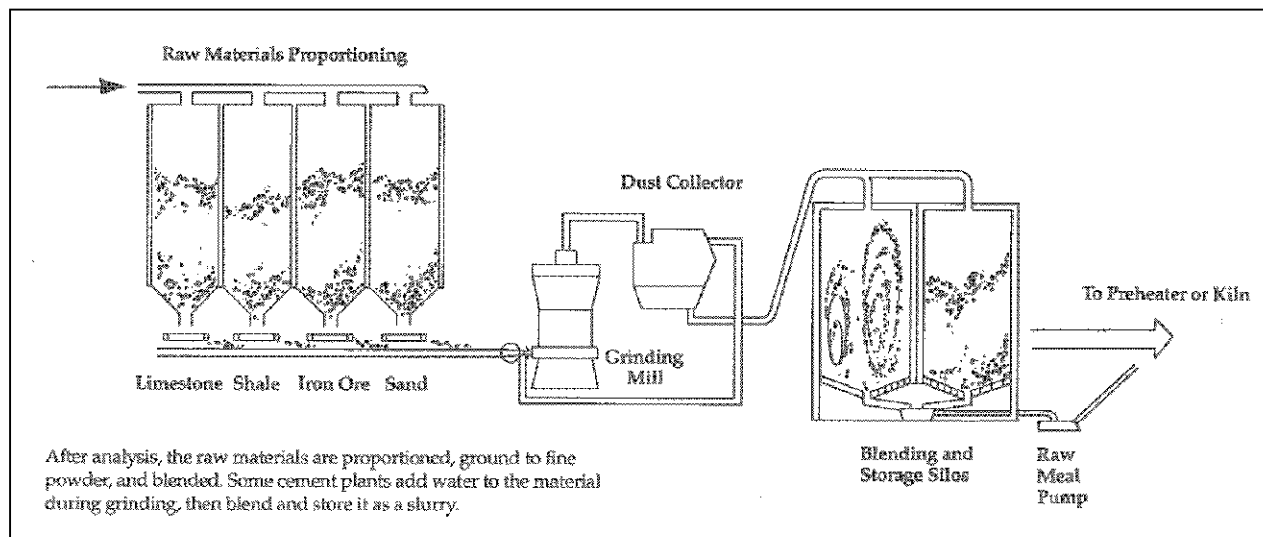
**Figure 2.** Mining and crushing of the raw materials is the first step in the cement making process. Illustration from American Portland Cement Association, (1992).

In its Annual Report XV, the Iowa Geological Survey reported on the Cement Materials of Iowa (Eckel and Bain, 1905). They analyzed Cedar Valley limestones from north-central Iowa and, while noting that the rocks became increasingly “magnesian” (dolomitized) to the north, they concluded that some of the beds were “sufficiently free of magnesia to be suitable for cement material.” They also noted the presence of Lime Creek shales (another possible ingredient for cement production) in the area. They concluded that, “In the vicinity of Mason City where these (shale) beds outcrop there are extensive exposures of the non-magnesian beds of the underlying Cedar Valley, and it should be possible to combine the two to advantage.”

In Iowa Geological Survey Annual Report XVII Beyers (1907) reported on Physical Tests of Iowa Limes. Among the materials analyzed was lime produced from the limestones of the Devonian Cedar Valley at Mason City. The reported the chemical analyses of various burned lime products, and the tensile strength of briquettes produced with various lime/sand mixtures, and other characteristics of the material.

With this information in hand, the Northwestern States Portland Cement Company opened the first cement plant in this area of the Midwest in 1908. The plant, with the original capacity to produce 250,000 tons of cement per year, grew with the town of Mason City for 82 years. A second kiln brought the plant to its current capacity of 900,000 tons per year.

In 1990 the plant was purchased and later merged into Holnam Inc. (Fig. 1), the largest cement manufacturer in the United States. Holnam Inc. employs nearly 200 workers at its Mason City cement plant, paying more than \$6.7 million annually in wages and benefits. Additionally the company pays more than \$750,000 in state and local taxes yearly.



**Figure 3.** The second stage in the cement making process involves mixing and grinding of the raw materials prior to firing in the kiln. Illustration from American Portland Cement Association, (1992).

### HOW CEMENT WORKS

When cement is mixed in the proper proportions with aggregate (stone and sand) and water, a series of mechanical and chemical actions is triggered. A typical mixture includes 11% Portland cement, 16% water, 26 % sand or other fine aggregate, and 41% gravel, crushed stone, or other coarse aggregate. Additionally, most cement mixtures include about 6% air. As the ingredients are mixed, the water combines with the cement to form a paste which coats the aggregate grains and fills the pore spaces between them. The water also begins a chemical reaction with the cement called hydration, initially forming a gel which subsequently hardens binding the aggregate into a solid mass which strengthens with time. This reaction does not require oxygen, allowing cement to harden even when poured under water. The rate at which the cement hardens is controlled by the addition of ground gypsum to the cement when it is manufactured. The hardening of the cement must be slow enough to allow the concrete to be poured and finished while it is still in its plastic state, and yet fast enough that it doesn't delay further construction. Cements with various setting times for various applications are produced at the cement plant. Temperature also affects the setting time of cement, so the cement formulation is adjusted seasonally. Although cement attains most of its strength within a few days of being poured, if moisture is present, the cement will continue to gain strength by continuing hydration for many years.

### WHAT GOES INTO HOLNAM'S MASON CITY PORTLAND CEMENT

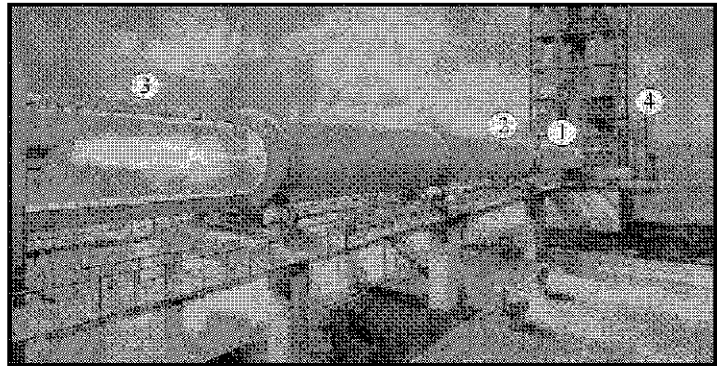
The principal component of the Portland cement that is produced by Holnam Inc. in Mason City is the limestone that is mined from the company's quarry, about 2 miles north of the cement plant. The lime-

stone ( $\text{CaCO}_3$ ) and minor associated karstic shales are derived from the basal 8 meters (25 feet) of the quarry, (Fig. XXXXX) and constitutes about 84% of the raw cement product. Additional materials that are added to the limestone include 10% kaolinite ( $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$  - from a Holnam quarry near Redwood Falls, Minnesota), 5% silica sand ( $\text{SiO}_2$  - originally mined near La Sueur, Minnesota, and used as foundry sand by John Deere before its use by Holnam), and about 1% “Blue Clay” (fine-grained glacial drift, probably lacustrine sediments). This material is ground (Fig. 2) until 80% passes 200 mesh (74 $\mu$  - silt-size) before it is introduced into the kiln.

### FIRING THE RAW MATERIALS

The ground raw materials are transformed into clinkers in long, sloping, cylindrical steel kilns. The Holnam’s Mason City plant has two cement kilns. The largest kiln is 590 feet long and 17½ feet in diameter, the other is 500 feet long and 15 feet in diameter. The kilns rotate at about 70 revolutions per hour. A 700 foot long kiln at a Holnam cement plant in Missouri is the world’s largest piece of moving industrial equipment. At the Holnam Mason City plant, the kilns are fired primarily with powdered low-sulfur coal from northwest Colorado and ground tires. The plant uses about 140,000 short tons of coal and about one million automobile tires per year. The combustion occurs at the lower end of the kiln, with the hot gasses moving up the length of the cylinders as the raw product moves down.

The ground raw material moves into the lower end of the kiln known as the precalciner (1 in Figure 4), where up to 95% of the carbon dioxide is removed from the limestone. Moving into the main part of the kiln, (2) the material tumbles through progressively hotter temperatures as it travels down the length of the rotating kiln. The last of the  $\text{CO}_2$  is driven off and the other chemical reactions are initiated. As the material reaches the lower end of the kiln (3) it encounters the highest temperatures. Flames as hot as 1870° C (3400°F) drive the material temperatures to almost 1480°C (2700°F). After two hours, the partially molten material finally emerges from the lower end of the kiln as red-hot particles called clinker. Meanwhile on the other end of the kiln the hot gasses pass from the pre-heat cyclone through a series of pollution control devices (4). The “kiln dust” or solid particulate mater that is collected by the pollution control devices is returned to the raw material flow for another run through the kiln. The clinker is then ground for bulk shipping or bagging (Fig. 5)



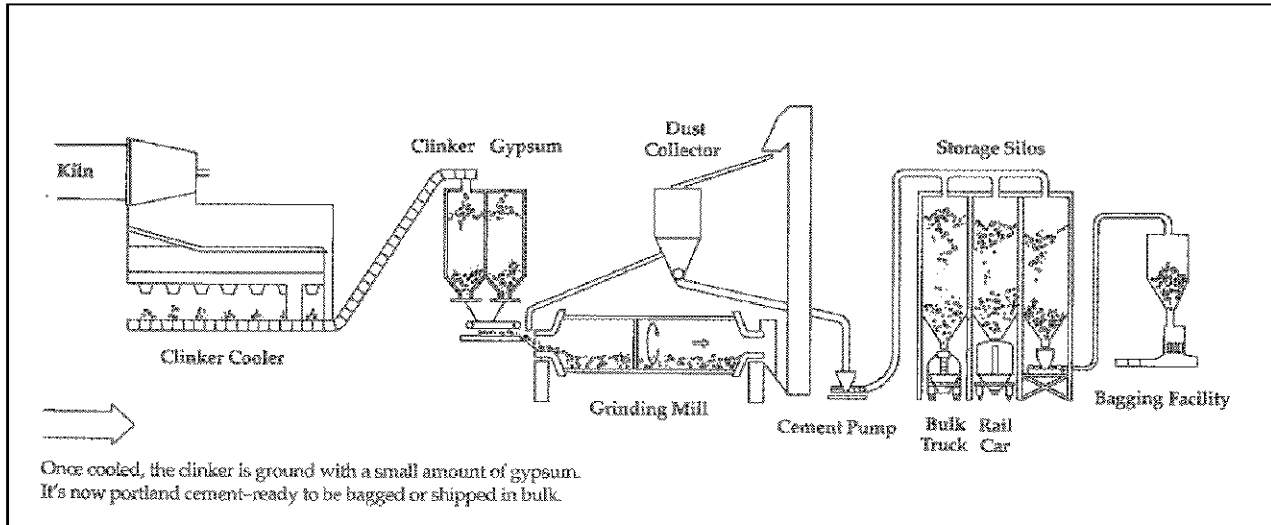
**Figure 4.** The raw materials move down the kiln (right to left on this illustration) towards the flame. Illustration from American Portland Cement Association, (1992).

### KILN CHEMISTRY

As the raw materials of cement tumble down the length of the rotating kiln (Fig. 6) they undergo a complex suite of chemical and physical changes, converting the calcium carbonate and silicon oxides into calcium silicates, the primary constants of cement. These reactions occur in three progressively hotter zones in the kilns.

1. In the Drying and Heating Zone, temperatures of 20 - 900°C (70 - 1650°F), water is evaporated and the calcium carbonate begins to be calcined (the process of driving  $\text{CO}_2$  off the  $\text{CaCO}_3$  to create  $\text{CaO}$  or calcium oxide).
2. In the Calcining Zone, temperatures of 600 - 900°C (1100 - 1650°F), calcination is completed.

- In the Sintering or Burning Zone, temperatures of 1200 - 1480°C (2200 - 2700°F), the calcium oxide reacts with the silica to form dicalcium silicates and alumina- and iron-bearing materials to form tricalcium aluminate and tetracalcium aluminoferrite. These two compounds (molten) combine with solid components of the mixture to form pellets called clinkers. The remaining calcium oxide reacts with dicalcium silicate to form tricalcium silicate.

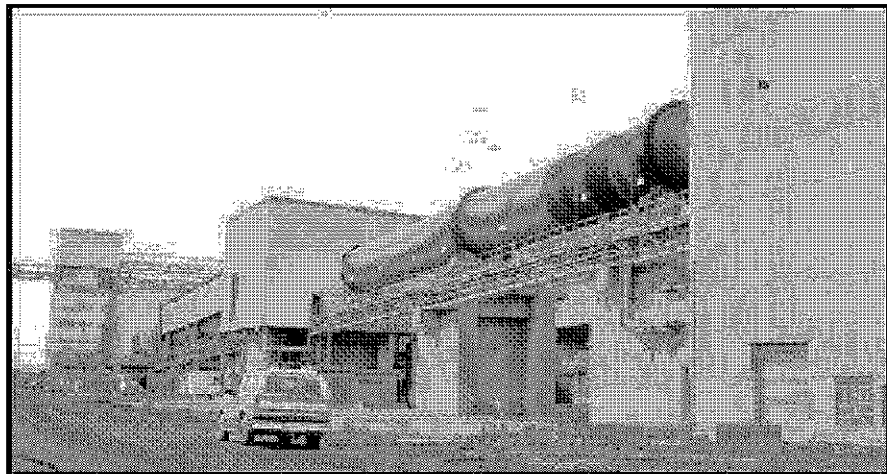


**Figure 5.** Finally, the raw product is fired to clinker, ground to produce cement, then shipped or bagged. Illustration from American Portland Cement Association, (1992).

### NEW CEMENT PRODUCTS UNDER DEVELOPMENT

The national demand for cement is growing faster than the industry's abilities to expand and provide this material. This delay is due, in part, to the large lead-time needed for the industry to address the environmental concerns at proposed new plant sites. About 5 years is required to complete the environmental assessments and devise strategies to reduce the adverse impact of the plant on the environment. Add to this about 2 years for the actual construction of the plant, and the problem is clear.

One solution to the cement shortfall is to produce more cement per ton of clinker. This is done by adding materials to the clinker. Currently, gypsum is the primary post-firing additive. The gypsum is added to control the cement setting time, and generally about 92% of cement is ground clinker, about 8% is gypsum. Holnam and other companies



**Figure 6.** One of the cement kilns at the Holnam Inc. plant. The largest of the two kilns is 590 feet long.

have been experimenting with adding blast furnace slag material and fly ash from power plants to produce more cement with a given volume of clinker material. Many of these new cement blends have proven to be lighter and stronger than traditional Portland cement.

### USES FOR CEMENT/CONCRETE

Portland cement, as concrete, has found its way into a variety of uses in our modern society. Nationally, about 22.8% of all concrete produced goes into the construction of industrial and commercial buildings, 21.2% into highways, streets, and bridges, 18.7% into one- and two-story family houses, 9.4% into public buildings, 6.7% for maintenance and repairs, 6.7% for water and waste systems, and 7.8% for other uses.

### POLLUTION PROBLEMS ASSOCIATED WITH CEMENT PLANTS

Despite the pollution controls employed, the process of producing cement can produce a variety of unwanted by-products. About one ton of CO<sub>2</sub> (a primary greenhouse gas) is produced for every ton of cement. Another unwanted by-product is particulate emission, including material from the smokestack and also dust from the mining, hauling and stock piles.

The cement making process can also have a positive environmental impact. The high temperatures of the kiln flame make it ideal for recycling wastes by recovering their energy value. Many wastes such as used motor oils, solvents, chemical byproducts have a high energy content. As supplemental fuels, they replaced significant quantities of traditional fossil fuels and provide a means of safely disposing of hazardous materials. The Holnam Mason City plant derives up to 15% of its energy from discarded automobile tires. The U.S. Environmental Protection Agency requires incinerators and other waste processors to achieve 99.99% destruction efficiency. Cement kilns easily reach this destructive level and are often 100 times more efficient.

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### **STOP 3: LUNCH AT CLEAR LAKE—LAKE HISTORY**

E. Arthur Bettis III

Clear Lake is Iowa's third largest natural lake. It is located along the eastern margin of the Des Moines Lobe and formed when the glacier was at the position marked by the Altamont-Algona ice margin complex. When the glacier advanced to this position several subglacial tunnels issued meltwater from the glacier front. Two of these, now occupied by Clear and Willow creeks, originally issued from a large subglacial tunnel now occupied by Clear Lake. Extensive sand and gravel deposits are present in these valleys east and northeast of Clear Lake. A thin layer of Des Moines Lobe glacial diamicton resting on Devonian Lime Creek shale floors Clear Lake. Baker and others (1992) analyzed pollen from a 10-meter long core taken from the deepest part of Clear Lake north of our lunch stop. The core provides a pollen sequence that spans the period from about 13,000 B.P. to the present. From deglaciation until about 10,000 B.P. the area was occupied by a closed coniferous forest that contained spruce, larch, and black ash. By 10,000 B.P. the coniferous forest was replaced by a mesic deciduous forest containing oak, elm, hornbeam, birch, and sugar maple. The forest persisted until about 8,000 B.P. when it was replaced by prairie. Prairie dominated until about 3800 B.P. when oak pollen increased in abundance signaling a change to savanna vegetation as effective moisture increased. The last major change in the pollen sequence occurs in the upper 30 cm of the core where a dramatic increase in the percentage of ragweed (*Ambrosia*) pollen marks historic agriculture's impact on the native vegetation.

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## **INTRODUCTION TO THE DES MOINES LOBE**

Deborah J. Quade and E. Arthur Bettis III

The afternoon portion of the 1998 Geological Society of Iowa trip will offer an opportunity to view the complex assemblage of glacial landforms associated with the Des Moines Lobe (DML) in Iowa and to examine the sediment sequences associated with the various landforms of the DML. The afternoon will consist of three stops. These stops are designed to acquaint trip attendees with : 1) DML lithostratigraphy, 2) an appreciation for the complexities associated with glacial landforms, and 3) environmental issues and land-use planning tools concerning the siting of animal confinement feeding operations (ACOs) on the DML. Figure 1 is a map that shows the four counties we will be traveling through, the moraine boundaries for the northeastern portion of the DML, and the locations of Stops 3 through 5. A map of Stop 6 in Wright County is included in the Stop 6 discussion.

For much of the trip we will be traveling on the Algona-Altamont Moraine Complex and the Altamont Moraine Complex. The age of the DML is well established by numerous radiocarbon dates (Bettis et al., 1996). The Lobe advanced into Iowa before 15,000 radiocarbon years before present (RCYBP) and reached its terminal position, Des Moines, Iowa approximately 13,800 RCYBP. Later, the Lobe readvanced to the position of the Altamont ice margin (just north of Ames) approximately 13,500 RCYBP. Several minor readvances, marked by the Clare, Renwick, and West Bend Moraines occurred between 13,500 and 12,600 RCYBP; these moraines are discontinuous. The final advance into Iowa, the Algona occurred about 12,300 RCYBP. Rapid stagnation and wastage of the glacier also followed this advance.

The DML was active in Iowa from about 15,000 to 12,000 RCYBP, approximately 5,000 to 8,000 years later than glacial lobes to the east reached their southernmost positions (Johnson, 1986; Fullerton, 1986). Kemmis and others (1994) concluded that the advance of the DML occurred during a period of regional warming and therefore was an out-of-equilibrium surge. Kemmis (1991) noted that glacial landform types and sedimentary sequences of the DML were different than those associated with Lobes in Illinois and Wisconsin. Kemmis and others (1981) developed a classification for DML sediments that grouped sediments by easily recognized properties, readily observed in the field. Upland glacial deposits of the DML were grouped into the Dows Formation. Bettis and others (1996) further refined and described the lithostratigraphic framework for the DML to include four formations. Included below is a discussion of the Dows Formation and its four members from Bettis and others (1996). Figure 2 illustrates the lithostratigraphic sequence for the DML.

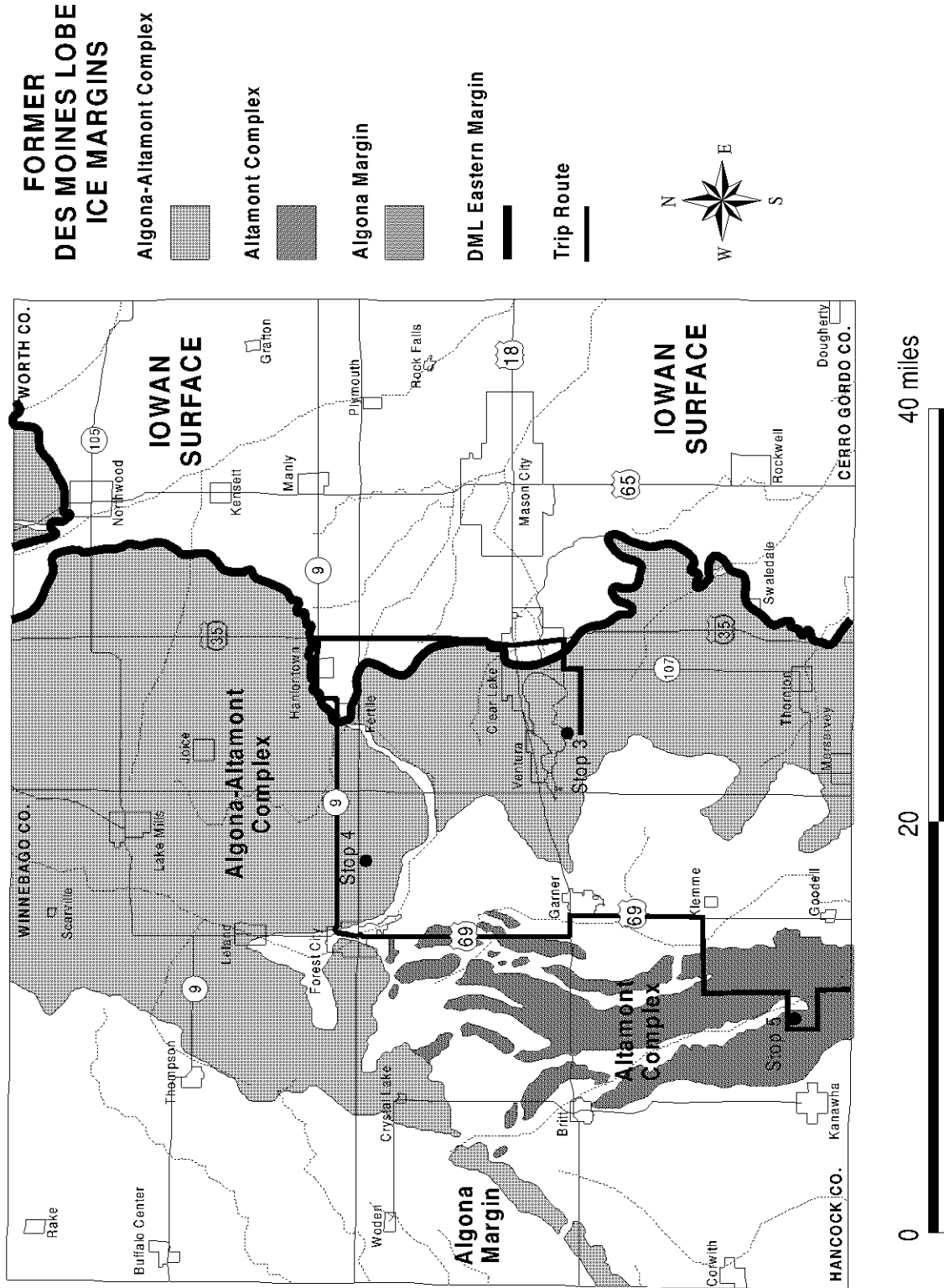


Figure 1. Map showing Stops 3 through 5 with respect to former ice margins associated with the northeastern Des Moines Lobe, Iowa

## DOWS FORMATION

The Dows Formation includes all upland glacial deposits on the Des Moines Lobe. The formation is subdivided into four different members: the Alden, Morgan, Lake Mills, and Pilot Knob members. Information on the formation as a whole is presented first, followed by that for individual members.

**Source of name:** the town of Dows, Franklin County, Iowa.

**Type Section:** the Martin-Marietta quarry located in the NW 1/4, NE 1/4, SE 1/4 of section 30, T. 91 N., R. 22 W., Franklin County, Iowa (Kemmis et al., 1981). The type section is located on the flanks of the high-relief Altamont glacial-ice margin complex.

**Description of Unit:** The Dows Formation includes all upland glacial deposits on the Des Moines Lobe in north-central Iowa. It is subdivided into four members. The Alden Member consists predominantly of massive, dense, compositionally uniform diamicton. The Morgan Member consists of diamictons interbedded with generally thin, discontinuous beds of sorted sands, silts, silty clays, and gravels. The Lake Mills Member consists predominantly of massive to laminated silts and silty clays, frequently with a thin basal zone of sand and gravel. The Pilot Knob Member consists predominantly of upland sands and gravels occasionally interbedded with thin, discontinuous diamicton beds. At the type section, the Dows Formation consists of deposits of the Alden Member overlain by the Morgan Member (Kemmis et al., 1981).

**Nature of Contacts:** The Dows Formation unconformably overlies various older stratigraphic units including proglacial sand and gravel deposited during lobe advances, Peoria Formation loess, older Wisconsinan glacial deposits of the Sheldon Creek Formation, diamictons of the Pre-Illinoian-age Wolf Creek and Alburnett formations, buried soils developed in diamictons of the Pre-Illinoian Wolf Creek and Alburnett formations or undifferentiated alluvial and colluvial deposits overlying these formations, Cretaceous-age shale, various Pennsylvanian-age sedimentary rocks, and Mississippian- and Devonian-age carbonate rocks. The formation usually overlies Quaternary sediments. It rests on Cretaceous-, Pennsylvanian-, Mississippian-, and Devonian-age bedrock in only small, restricted areas.

The formation is at the surface over most of north-central Iowa, except on outwash plains where it is buried by sand and gravel of the Noah Creek Formation. Locally the Dows Formation is overlain by younger colluvial, alluvial, or paludal sediment of the DeForest Formation. In stream valleys, the Noah Creek and DeForest Formations are often incised through the formation.

**Differentiation from other Units:** The Dows Formation is distinguished by its distinctive clay mineralogy. Compared to other formations, the massive diamicton is higher in expandable clay minerals (smectite group) and, unlike other northern-source glacial formations (Sheldon Creek, Wolf Creek, and Alburnett formations), the illite percentages are higher than the kaolinite-plus-chlorite percentages.

The distinctive clay mineralogy of the Dows Formation is similar to the clay mineralogy of Cretaceous-age Pierre Shale, a distinctive bedrock lithology that was glacially eroded and incorporated into the Dows Formation. The clay-mineral composition of fifteen Pierre Shale fragments taken from the Dows Formation is 67±3% expandables, 27±3% illite, and 6±2% kaolinite plus chlorite (Kemmis et al., 1981). This compares with the clay mineralogy of the fine-grained matrix of massive Dows Formation diamictons of 69±4% expandables, 19±3% illite, and 12±3% kaolinite plus chlorite.

**Regional Extent and Thickness:** The Dows Formation is continuous across uplands on the Des Moines Lobe in Iowa. Formation and member thicknesses vary. The formation is typically 15 to 20 m (45 to 60 ft) thick across most of the Lobe. It thickens to over 30 m in ridges and escarpments deposited at the edge of former ice advances ("end moraines"). Stream valleys are cut into or through the upland Dows Formation deposits; the lower reaches of most major streams, such as the Des Moines, Iowa, Raccoon, and Boone rivers, have incised completely through the Dows Formation sequence at many sites.

**Origin:** The Dows Formation includes all upland glacial deposits on the Des Moines Lobe. Members of the formation are distinguished by their characteristic lithologic. Although these properties are not defined by the origin of the deposits, the members are usually associated with distinctive glacial environments. The massive diamicton of the Alden Member is usually till that has been deposited in a subglacial environment. The interbedded diamicton and sorted deposits of the Morgan Member were usually deposited

in ice-marginal and supraglacial settings. The fine-grained, generally pebble-free deposits of the Lake Mills Member usually were deposited in glacial lakes. The coarse-grained, sand-and-gravel deposits of the Pilot Knob Member are found in the core of kame and esker landforms deposited in association with glacial meltwater.

**Age and Correlation:** The Dows Formation was deposited by advances of the Des Moines Lobe dating from approximately 15,000 to 12,000 radiocarbon years before present (Kemmis et al., 1981; Ruhe, 1969). The formation is correlative to the New Ulm Till of Minnesota (Hallberg and Kemmis, 1986) for which Matsch (1972) provides limited textural and compositional data.

		Upland			Valley
Wisconsin Episode	Peoria Formation <i>sand and silt facies</i>	Dows Formation	Morgan Member <i>resedimented diamicton</i>	Lake Mills Member <i>glaciolacustrine sediments</i>	Pilot Knob Member <i>ice-contact glaciofluvial sediments</i>
			Alden Member <i>massive diamicton</i>		
Hudson Episode		DeForest Formation	Undifferentiated <i>fine-grained sediments</i>	Flack Member <i>loamy colluvial sediments</i>	Woden Member <i>organic-rich sediments</i>
					Undifferentiated <i>fine-grained sediments</i>

Figure 2. Lithostratigraphy of the Des Moines Lobe region, Iowa.

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**ROAD LOG FOR DES MOINES LOBE (DML)**

<b>Acc. Mileage (miles)</b>	<b>Distance (miles)</b>	<b>Notes</b>
0.0	0.0	Clear Lake State Park Lodge. <b>Stop 3 and Lunch--Clear Lake.</b>
0.3	0.3	Turn left (east) onto Hwy. B35 (Southshore Dr.).
0.9	0.6	Turn right (east) on Hwy. B35 (27 <sup>th</sup> Ave. S.).
2.4	1.5	Turn left (north) on Hwy. B35 (Grouse Ave.).
3.5	1.1	Turn right (east) on 4 <sup>th</sup> Ave. S. (follow I-35 signs).
4.2	0.7	Turn left on ramp for I-35 North.
5.1	0.9	Note borrow pits on right. Sand & gravel excavated for I-35.
5.5	0.4	More borrow pits on right and left sides of I-35. These pits are located on outwash associated with the eastern margin of the Altamont Moraine.
7.7	2.2	Driving north onto eastern edge of a broad hummocky escarpment—Algona-Altamont ice margin complex.
8.3	0.6	Note view to the west of moderate-relief hummocky topography.
8.8	0.5	Driving off the eastern margin of the DML.
12.0	3.2	Note animal confinement operation (ACO) to the east.
13.5	1.5	Cross Winnebago River Valley. This river heads along the Algona glacial margin and in this area flows behind a hummocky ridge system related to the Altamont glacial advance. Worth County line.
14.6	1.1	Crossing low-relief area; outwash plain associated with the Algona-Altamont ice margin complex.
15.0	0.4	Take a right on Exit 203 Hanlontown, Pilot Knob State Park, Hwy. 9.
16.5	1.5	Take a left on Hwy 9 and continue west.
16.8	0.3	Passing by Hanlontown. This area was once home to several prosperous peat mining companies; Ely Colby Peat Company and Colby Pioneer Peat Company. Later, these companies merged. However, peat supplies near Hanlontown were depleted and the company moved north to mine peat on the south end of Rice Lake.
18.3	1.5	Driving onto the Algona-Altamont frontal margin.
18.7	0.4	Note cemetery to the right. We are quickly approaching an old lake bed associated with the margin of the Algona-Altamont ice margin complex.
19.4	0.7	Look right at the low-lying area; this is Goose Lake—the north end of this lake bed was once the site of extensive peat mining.
20.0	0.6	Passing by Fertile, Iowa. We are climbing onto the Algona-Altamont ice margin complex.
22.4	2.4	Note moderate to high relief hummocky topography associated with the frontal margin of the Algona-Altamont ice margin complex.
23.4	1.0	Note sand and gravel pit in an esker-like ridge on right at the intersection with Hwy S14. This is the reference section (LaHarv-1) for the Pilot Knob Member. There is a discussion and description of this section included at Stop 4: Pilot Knob State Park.
24.3	0.9	Winnebago County line.
26.9	2.6	Note Hwy. R74. Approximately 10 miles north is the town of Lake

Mills, IA. This area is the reference section for the Lake Mills Mbr.—glacial lake sediments.

- |      |      |  |
|------|------|--|
| 27.9 | 1.0  | Turn left on road into Pilot Knob State Park and drive through hummocky ridge system with well expressed linked-depression systems. Park entrance. Proceed straight to parking lot. <b>Stop 4: PILOT KNOB STATE PARK.</b>  |
| 28.9 | 1.0  | Stop sign. Turn left and proceed west on State Hwy. 9. As we proceed toward Forest City we are now driving through a hummocky ridge system on the up-ice side of the Algona ice margin.  |
| 31.9 | 3.0  | Enter Winnebago River Valley.  |
| 32.1 | 0.2  | Stoplight. Turn left on US Hwy. 69. Just south of the Municipal Airport we rise up onto an elongate, slightly sinuous beaded ridge (esker) that trends roughly east-west from a large, moderate relief, short-slope hummock. This landform complex is part of an elongate, north-south trending hummocky ridge system that marks one of the Altamont advances along the eastern portion of the DML in Iowa. The ridge is bordered on the south by a tributary of the Winnebago River.<br><br>The 41 Madison site is located in a gravel pit on the beaded ridge, and exposes Pilot Knob Mbr. deposits. The general stratigraphy consists of two units: stratified meltwater sands and gravels overlain by a 1.5-2 m thick veneer of stratified diamicton (Kemmis, 1991).<br><br>Soils mapped on the ridge and hummock complex are complexes of the Clarion and Sunburg series, and the Sunburg and Salida series (Lensch, 1989). Clarion and Sunburg soils are formed in glacial till, while Salida soils are formed in outwash. The Clarion and Sunburg soils at this locality are formed in the stratified diamicton deposits that form a veneer on the ridge. Because the soil thicknesses (0.3 to 1.5 m; 1 to 5 ft) are thinner than the diamicton veneer of 1.5 to 2 m (4 to 6 ft), the soil map neither portrays the thick sands and gravels which are mineable at the site nor gives a complete indication of the material sequence present. This is a common limitation of soil maps on the DML: the shallow depth of mapping (1.5 m or 5 ft) does not accurately indicate the stratigraphic sequence at many sites, and thus soil maps are of limited use for geologic interpretation, land-use planning, and other applied purposes in which it is essential to know properties at depths greater than 1.5 meters.<br><br>As we proceed south to Garner we will cross over a series of discontinuous hummocky ridge systems and intervening plains with irregular surface patterns associated with the Altamont ice margin complex. We also will cross the East Branch Iowa River which carried meltwater from both the Altamont and Algona ice margins. |
| 43.3 | 11.2 | Stop sign. Turn left on US Hwy. 18 and proceed east.   |
| 43.9 | 0.6  | Cross East Branch Iowa River.  |
| 44.3 | 0.4  | Stop sign. Turn right on US Hwy. 69 and proceed south through a plain with linked-depression systems.  |

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50.8	6.5	Turn right on B55 and proceed west.
51.4	0.6	Cross East Branch Iowa River. This valley is associated with the Algona and Altamont glacial advances.
52.5	1.1	Enter a plain with irregular surface patterns once you cross the East Branch, then ascend a hummocky ridge system. The series of gravel pits to the right are located in the uplands. Pilot Knob Mbr. sand and gravel deposits are being mined from these pits.
53.7	1.2	Turn left and proceed south on County Rd. R56. Note well developed linked-depression systems on both sides of the highway.
57.5	3.8	Turn right on 130 <sup>th</sup> St.
57.9	0.4	Drop into West Branch Iowa River valley. This drainage line is associated with the southern margin of the Algona glacial advance.
58.3	0.4	Cross West Branch Iowa River.
59.0	0.7	Thompson EMS site to the left. Note basin to the east of the confinement buildings that is located in a linked drainageway.
59.5	0.5	Turn left and proceed south on Nash Ave.
59.7	0.2	<b>Stop 5. Thompson EMS Site.</b> Turn left into entrance to EMS site.
60.2	0.5	Stop sign. Turn left on 120 <sup>th</sup> St and proceed east.
60.8	0.6	On right is the parking lot for Twin Lakes State Wildlife Management Area. These lakes are part of a linked-depression system that joins the West Branch Iowa River. McCulloch Bog, one of Walker's (1966) study areas, is located about 1.5 miles south in this linked-depression system.
61.2	0.4	Cross West Branch Iowa River.
62.2	1.0	Stop sign. Turn right on County Rd. R56 and proceed south through a hummocky plateau area.
63.2	1.0	Stop sign. Cross County Rd. B63 and proceed south on Page Ave.
64.9	1.7	To left is a large-scale EMS site. The lagoon is situated in part of a linked-depression system that joins the West Branch Iowa River.
65.2	0.3	Turn right on 110 <sup>th</sup> St.
65.6	0.4	To the right is another large-scale EMS site. The lagoon is located at the head of the drainageway of the same tributary we crossed.
68.1	2.5	Stop sign. Turn left on Madison Ave. and proceed south.
70.1	2.0	Stop sign. Cross County Rd. C20 and proceed south on County Rd. R38. Drive up backside of Altamont ice margin complex.
72.9	2.8	Descend Altamont ice margin complex.
73.0	0.1	To the left is a wetland, the site of a plugged ADW and the headwaters of Little Eagle Creek which drains the Altamont ice margin complex.
77.9	4.9	Enter Clarion.
78.7	0.8	Stoplight. Turn left and proceed east on State Hwy. 3.
78.8	0.1	On left note the home of the 4-H emblem.

Jessie Field Shambaugh of Shenandoah was an educator who embraced the ideals of farm living in the early 1900s. She involved her students in Girls Home Clubs and Boys Corn Clubs. Their award pin was shaped like a clover with an "H" on each leaf.

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O.H. Benson, a Clarion educator who established similar clubs in Wright County, took the pin to a national conference, and it eventually became the symbol of farm youth clubs worldwide. The four “H’s” in 4-H represent head, heart, hands, and health.

- |      |     |   |
|------|-----|---|
| 82.6 | 3.8 | Turn right and proceed south Hwy. 69. Driving on moderately hummocky ridge system associated with the Altamont ice margin complex.  |
| 84.6 | 2.0 | Note EMS sites to the left and right. Wright County has 17% of the permitted EMS operations on the DML, and 8% of the permitted EMS sites statewide. Permitted EMS sites in Wright County house approximately 410,000 head of hogs. Hogs far outnumber humans, in this county-- <i>at least 30 to 1</i> . |
| 85.7 | 1.1 | To the left note one of the many ice margins that make up the Altamont ice margin complex. More EMS units to right and left.  |
| 87.0 | 1.3 | Poultry facility and grain elevator to the left.  |
| 88.4 | 1.4 | Turn right on Co. Hwy. C54 (270 <sup>th</sup> St.).   |
| 89.2 | 0.8 | Last stop of GSI Trip. <b>Stop 6: Wright County Agricultural Drainage Wells/ Animal Confinement Operations--Discussion.</b>   |

## **STOP 4: PILOT KNOB STATE PARK**

Deborah J. Quade and E. Arthur Bettis III

### **INTRODUCTION**

Pilot Knob is an excellent starting point for the afternoon portion of GSI field trip. On the drive from Clear Lake to Pilot Knob as well as the remainder of our travels along the eastern margin of the DML we will have an opportunity to view some of the more spectacular high-relief hummock topography and associated linked-depression drainage features on the DML in Iowa.

### **HISTORY OF PILOT KNOB PARK**

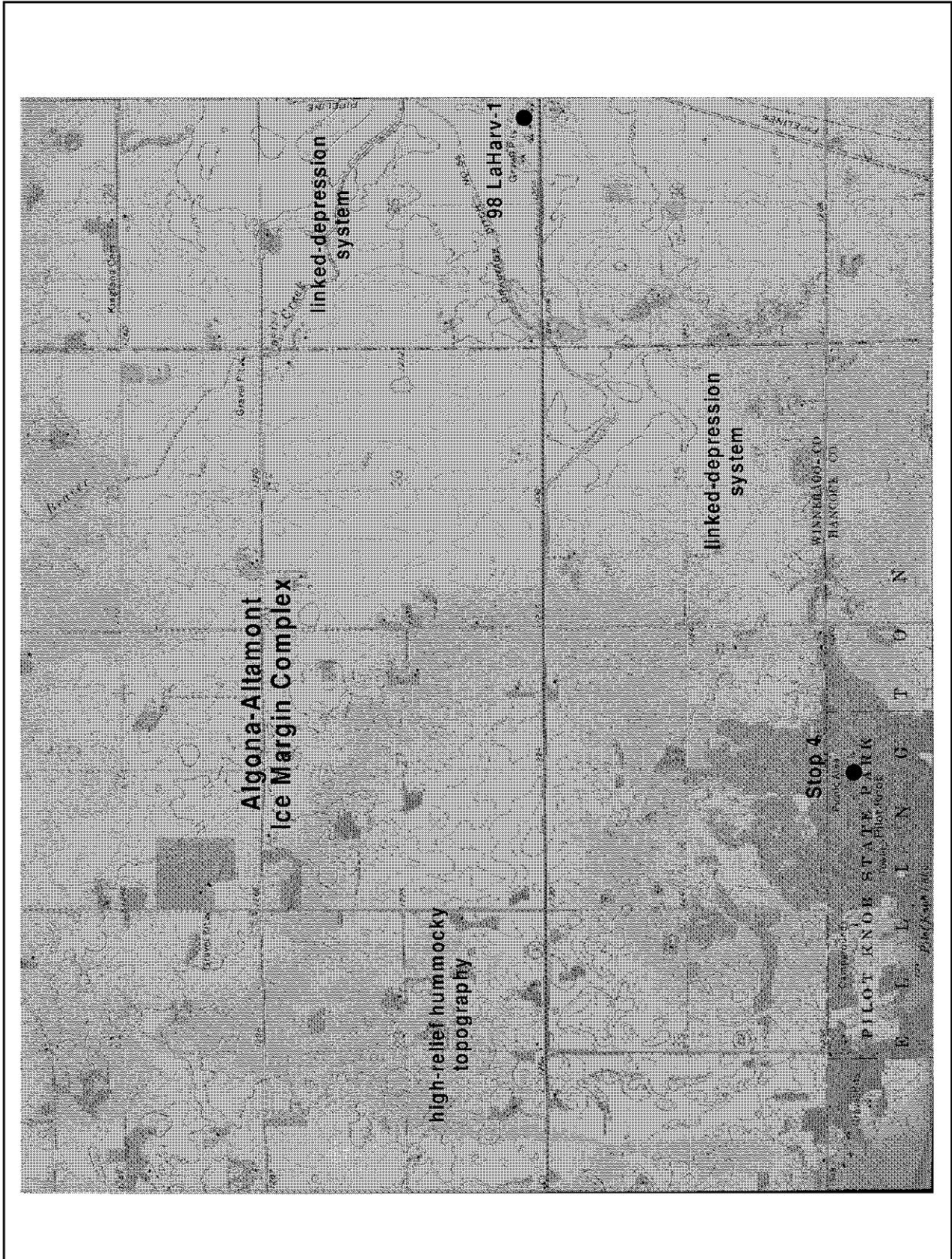
Pilot Knob rises approximately 300 feet above the Winnebago River and affords one of the most commanding views in Iowa. For early settlers, the knobs of this area served as “pilots” for navigating across the expansive tall grass prairie (Gwynne, 1952); thus the area became known as Pilot Knob.

Pilot Knob State Park was officially dedicated in 1924, after a coalition of local citizens took the initiative to preserve the area for future generations (Jackson, 1981). In 1934, a group of Civilian Conservation Corp (CCC) workers undertook building and landscaping projects at the park. Within four months the CCC work crew constructed roads, trails, a rock shelter, an outdoor amphitheater and the thirty-five foot observation tower. Glacial erratics were collected locally for construction of the buildings and tower. In 1968, the entire park (365 acres) received preserve status and in 1978 an additional 160 acres was acquired for park land. However, the most recent acreage purchase is not included in the preserve status (Watson, 1989).

### **GEOLOGY OF PILOT KNOB PARK**

The hummocky high-relief topography of the Algona-Altamont Moraine Complex is easily viewed in and near the confines of Pilot Knob State Park. The conical-shaped knobs and associated swales have classically been referred to as knob and kettle topography (Figure 1). The Pilot Knob area is part of a broad zone of supraglacial sedimentation. A stagnating ice margin is likely responsible for producing the broad belt of hummocky terrain along the eastern lateral margin of the DML. The ice stagnated in this area between approximately 13,500 and 12,000 years before present.

The deposits of the DML are classified into a lithostratigraphic framework that was adopted from an initial classification by Kemmis and others (1981). The Dows Formation is sub-divided into four different members: the Alden, Morgan, Lake Mills, and Pilot Knob members. For purposes of our discussion at Pilot Knob Park we have included a detailed description of the Pilot Knob Member (Bettis et al., 1996) and a short discussion on the reference section for the Pilot Knob Member (98 LaHarv-1) of Kemmis (1991).



**Figure 1.** Location of Pilot Knob State Park and the 98 LaHarv-1 section, reference section of the Dows Fm.- Pilot Knob Mbr., in Worth County, Iowa. Base from U.S.G.S. Pilot Knob 7.5' quadrangle.

## PILOT KNOB MEMBER

**Source of name:** Pilot Knob, the prominent glacial hummock in Pilot Knob State Park, located east of Forest City, Winnebago County, Iowa.

**Reference Section:** Deposits of the Pilot Knob Member are not present at the type section for the Dows Formation at Alden Quarry in Hardin county, but are well exposed in an excavation at the 98 LaHarv-1 site, located in an east-west trending esker in the NE 1/4, SE 1/4, SE 1/4 of section 30, T. 98 N., R. 22 W., Worth County, Iowa which is designated as the reference section for the member.

**Description of the Unit:** The Pilot Knob Member consists predominantly of sands and gravels occurring in irregularly shaped hummocks and low-sinuosity ridges in uplands on the Des Moines Lobe. Textures and bedding structures often vary significantly over short distances both laterally and vertically. Bedding structures include all of the flow-regime bedforms described by Simons and others (1965) and the various channel-fill types recognized by Ramos and Sopena (1983). Beds of virtually pebble-free, fine-grained sediment and diamictons sometimes occur at the top of or within the member, but are uncommon. The diamicton beds tend to occur as isolated, channelized pods. The stratified sequence comprising the member is sometimes offset by high-angle normal and reverse faults resulting from collapse of the sediment when the glacier's supporting ice walls melted away. The modern soil profile is developed in the top of the Pilot Knob Member where it is the surficial deposit. Sands and gravels within the member are oxidized where they occur above the water table and unoxidized below.

**Nature of Contacts:** The base of the Pilot Knob Member is rarely exposed. It is presumed to be unconformable on underlying diamicton sequences of the Morgan Member or the massive diamicton of the Alden Member. At many sites the Pilot Knob Member occurs at the land surface. At some sites it is overlain unconformably by 3 m (10 ft) or less of interbedded diamictons and sorted sediments of the Morgan Member or by a stoneline and thin colluvium of the Flack Member of the DeForest Formation.

**Differentiation from Other Members and Formations:** Unlike all other members of the Dows Formation, the Pilot Knob Member is composed predominantly of coarse sand and gravel. Although diamicton beds are locally present in the member, they do not comprise the bulk of the sequence as they do in the Morgan Member.

The sand and gravel sediments comprising the Pilot Knob Member are similar to the fluvial and glacio-fluvial sands and gravels of the Noah Creek Formation, but there tends to be greater variability, both laterally and vertically in the Pilot Knob Member. The Pilot Knob Member also occupies a distinct geomorphic position, that being upland hummocks and ridges, whereas the Noah Creek Formation is confined to stream valleys and outwash plains.

**Extent and Thickness:** The Pilot Knob Member occurs in irregular hummocks and low-sinuosity ridges across the Des Moines Lobe. The hummocks are usually a few hundred meters in diameter, and the narrow, sometimes beaded ridges usually extend from 1 to 3 km (1/2 to 1 1/2 mile). Relief on the hummocks and ridges is usually 6 to 13 m (20 to 40 ft), but locally may be greater. The range of thicknesses for the member is uncertain, but is generally greater than 3 m (10 ft). Maximum thicknesses are estimated to be 10 to 15 m (30 to 50 ft).

**Origin:** Like classic kames and eskers (e.g., Flint, 1971; Banerjee and McDonald, 1975; Saunderson, 1975; Sugden and John, 1976), deposits of the Pilot Knob Member appear to have formed in stagnant-ice environments. The sands and gravels were probably deposited by meltwater flowing in *moulins* and subglacial and *englacial* tunnels. Diamicton beds within the member appear to be debris flows into the tunnels as surrounding ice melted. High-angle normal and reversed faults within the Member formed when the sediments collapsed as surrounding ice walls melted away.

## 98 LaHarv-1

The gravel pit, 98 LaHarv-1, is the reference section for the Pilot Knob Member. This excavation is located approximately three miles northeast of Pilot Knob State Park at the intersection of Highway 9 and County Road S14. This site was described by Kemmis (1991) as an elongate, east-west trending esker-like ridge occurring in a high-relief hummocky area adjacent to a linked-depression system associated with Beaver Creek. Kemmis noted that esker-like ridges and kame-shaped knobs are not common on the DML, but are confined to high-relief hummocky areas and the mouths of larger drainageways along the lateral margins of the DML. Figure 2 illustrates the sediment sequence exposed in the core of the ridge at the 98 LaHarv-1 site.

## VEGETATION CHANGES AT PILOT KNOB STATE PARK

Baker and Kim studied a core from Dead Man's Lake in 1979 and reported their findings in Anderson and others, 1984. According to Baker and Kim the vegetation around Dead Man's Lake changed from savanna to prairie approximately 8,000 years ago. By 3,000 years ago the prairie was replaced by oak forest. Later, evidence of European settlement is apparent in the core with the appearance of certain weedy groups, primarily *Ambrosia* (ragweed). Apparently little is known about the interval of time from 12,000 to 8,000 years ago. Personal communication with R.G. Baker confirmed that poor recovery of samples and the inability to core through coarser sediments hindered Baker and Kim's efforts at collecting a deeper core. Unfortunately, it is this information which would yield valuable paleoclimatic information concerning the presence of sphagnum moss at this site.

## DEAD MAN'S LAKE

Carol A. Thompson

Dead Man's Lake is one of the most unusual wetlands in Iowa. It has been described as a "bog" by most authors, but is actually a nutrient-poor fen. Fens are separated from bogs by water chemistry, in particular pH, which is obviously a reflection of water source. Bogs have a pH of usually below 4.0 and are fed primarily by rainwater, thus the acidic pH. MacBride described Dead Man's Lake as "fed by springs, cold and clear..." however, while the chemistry reflects some groundwater inputs, it does not match that from the true spring-fed fens in Iowa (MacBride, 1902). The lake itself sits in a small depression on the Altamont ice margin. Local relief is about 45 feet. Details of the local geology are not known, but in general the deposits surrounding the fen are ice-contact glaciofluvial materials. Thus, the permeability may be high enough to allow groundwater to seep to Dead Man's Lake. The surficial drainage basin which probably mirrors the groundwater basin is small, covering only about 25 acres, thus inflow would be limited.

Dead Man's Lake is unusual in that the western part of the lake has a 3-acre floating mat present, dominated by *Sphagnum*. The mat, which once covered most of the lake, has been somewhat reduced in size by cutting and removal in the late 1920s (Grant and Thorne, 1955). The mean thickness of the mat is 2 feet. Its chemistry is somewhat variable depending on the time of year and whether a recent rain has occurred before sampling. The pH of the interstitial water varies from 4.1 to 5.7 in the center of the mat (Smith, 1962). The mat is surrounded by a 'moat' of open water characterized by neutral pH.

Dead Man's Lake is unusual not just because of its chemistry, but because of the plant community which it supports. The eastern part of the lake is primarily open water and supports a typical marsh and lake vegetation. However, the floating mat contains two species, *Carex cephalantha* (sedge) and *Drosera rotundifolia* (sundew), which are found nowhere else in the state (Watson, 1989). An additional three



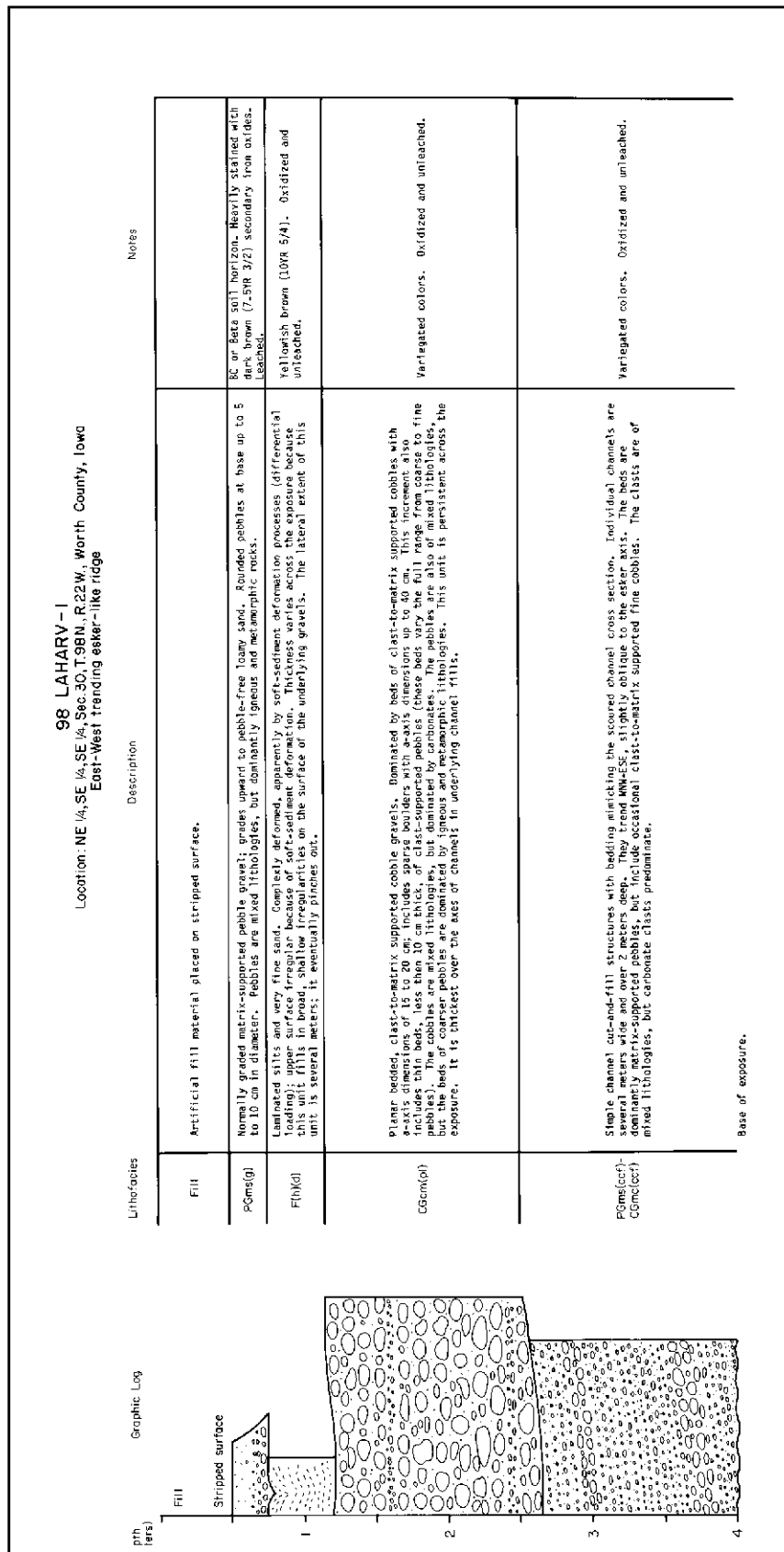


Figure 2. Lithofacies profile from 98 LaHarv-1. Description of sedimentary sequence for the Pilot Knob Mbr. reference section (Kemmis, 1991).

species, *Carex chordorrhiza* (sedge), *Eriophorum gracile* (cotton grass), and *Potentilla palustris* (marsh cinquefoil), are common on the mat, but rare in the rest of the state.

The high acidity and low dissolved oxygen limit the habitat for aquatic organisms. Smith and Bovbjerg (1958) noted low numbers both for number of species and total individuals in below mat waters. By contrast, however, the number of diatoms species is larger than found in many spring-fed fens and Dead Man's Lake displays different taxa than found in most Iowa fens (Main and Busch, 1992).

A core from the center of the mat showed that the fen developed in the late Holocene, and that the lake was probably intermittently dry in the middle Holocene (R. G. Baker, personal communication).

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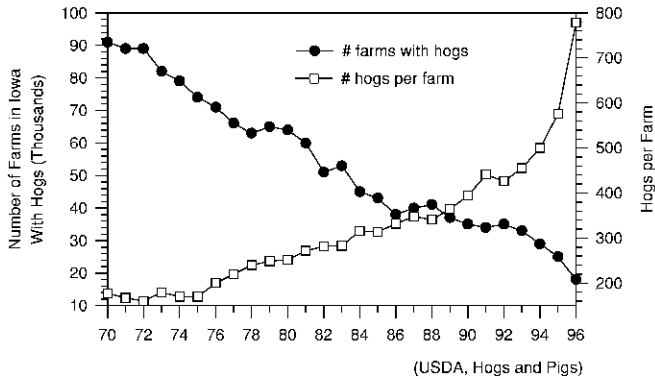


## AN INTRODUCTION TO HOGS IN IOWA

Lynette Seigley and Deborah J. Quade

### RECENT TRENDS

Iowa leads the nation in hog production, with 12.2 million hogs on hand as of December 1, 1996 (Sands and Holden, 1997). This represents 22% of the nation's hogs. Iowa is followed in hog production by North Carolina and Illinois. During the past several years, Iowa's share of all hogs marketed in the U.S. has ranged from 22 to 27% of the total (Otto and Lawrence, 1993). At both the national and state level, pork production has become more concentrated, with fewer farms owning more of the hogs. Figure 1 shows the number of farms with hogs in Iowa and the number of hogs per farm. The number of farms raising hogs has declined from 90,000 in 1970 to 18,000 in 1996, an 80% decline. At the same time, the number of hogs per farm has increased from 180 to 778, an increase of 332%. This trend has resulted in a rapid expansion of facilities with more than 1,000 head of hogs and a decline in the number of facilities raising smaller numbers of hogs.



**Figure 1.** Number of farms in Iowa with hogs and the number of hogs per farm in Iowa for the period 1970 through 1996.

During this time, the number of construction permits issued by the Iowa Department of Natural Resources (DNR) for confinement operations increased from an average of less than 10 permits annually during most of the 1980s to 170 being permitted in 1994 (Agena, 1998). Along with the increase in permits came concerns from the public over the social, economic, and environmental issues surrounding the rapid increase of these confinement facilities. Specific issues of concern included surface water and groundwater contamination, odor, and state versus local control of regulating these facilities. The following provides some perspective on the Iowa hog industry.

### PERMITTING PROCESS IN IOWA

The DNR administers the state's animal waste control program. Iowa's current Animal Feeding Operations rules are found in Chapter 65 of the Environmental Protection Commission Section 567 of the *Iowa Administrative Code* and are summarized in IDNR (1992). DNR rules define a confinement feeding operation as a totally roofed animal feeding operation in which wastes are stored or removed as a liquid or semi-liquid.

Over the years, changes have been made to Iowa's laws and rules that impact confinement operations. In 1995, House File 519 required submittal of a manure management plan that identifies land where ma-

nure is to be applied, and requires that total nitrogen application of fields receiving manure not exceed crop nitrogen needs. It also prohibits DNR from issuing additional permits to operations that have an enforcement action pending or to any person who has been classified as a habitual violator (three-strikes provision) (Agena, 1998).

In 1996, revisions to the Chapter 65 Animal Feeding Operations rules included specific design and construction standards (i.e., identifying and removing tile lines in the vicinity of anaerobic lagoons or earthen basins), established restrictions on the use of spray irrigation, and placed greater responsibilities on the site engineer to supervise critical points of construction (Agena, 1998). Manure storage basins and lagoons are constructed from available native materials and are designed to limit seepage to no more than 1/16 inch/day.

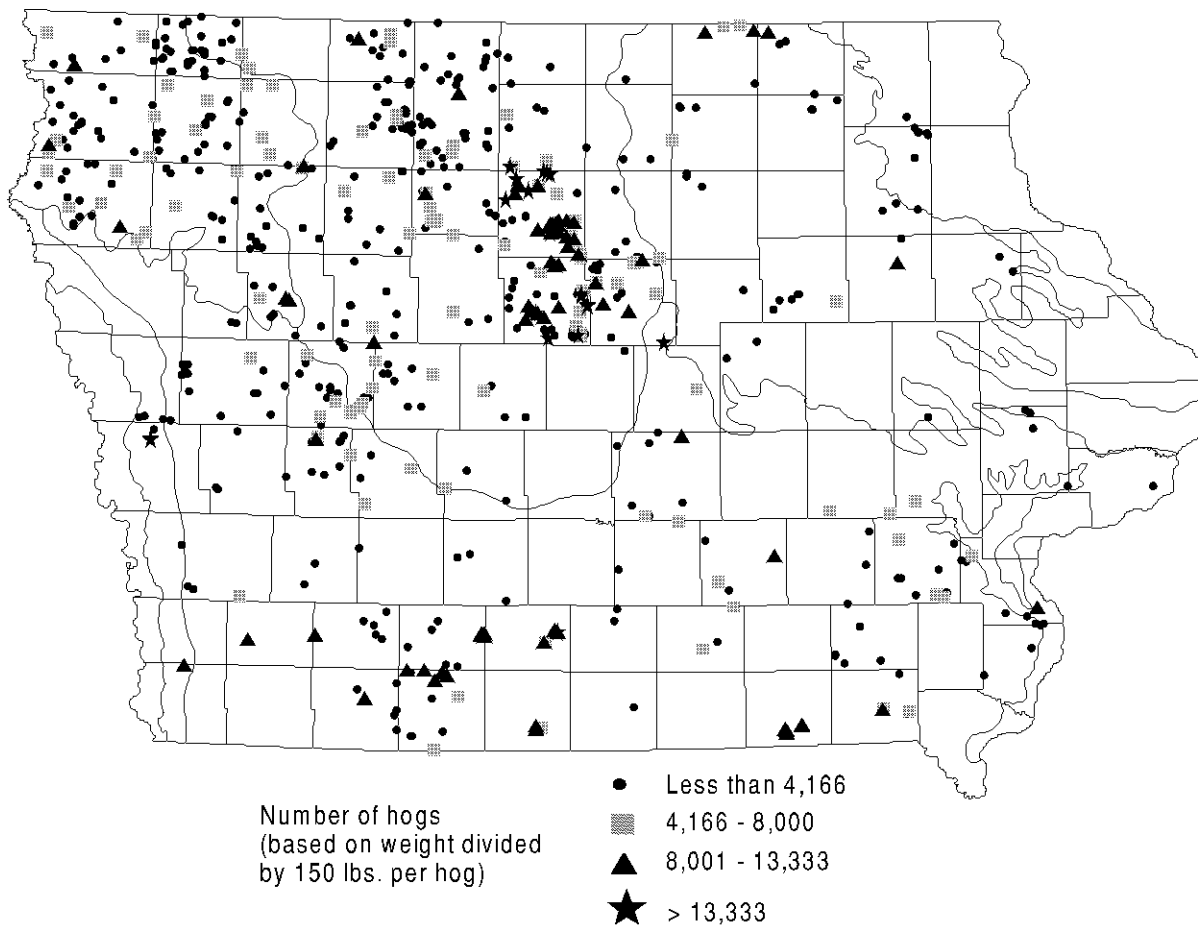
## DISTRIBUTION OF PERMITTED HOG CONFINEMENT FACILITIES

Figure 2 shows the distribution and size, by landform region, of permitted hog confinement facilities in Iowa. These facilities represent only those that required a permit from the DNR and were permitted from 1987 through December 1997. The number of hogs at each site is based on the live animal weight divided by 150 pounds. As of December 1997, there were 670 permitted hog confinement operations (HCOs) in Iowa. This number represents less than 4% of farms in Iowa with hogs. Approximately 308 of the 670 permitted sites (46%) are located on the Des Moines Lobe in north-central Iowa; 94 of these units (31%) contain more than 4,166 hogs. An estimated 1.5 million hogs reside in permitted sites on the Des Moines Lobe, and one-sixth of these (250,000) reside in HCOs with more than 13,333 hogs. (Note: These statistics are based on the permitted animal confinement operations database maintained by DNR.)

## MANURE STORAGE

The most common methods of manure storage in Iowa are formed tanks (concrete or steel), earthen basins, or anaerobic lagoons. The storage unit size depends on the amount of waste generated. The volume of waste generated varies on the type and weight of the animal, the feed that is being consumed, and the frequency of feeding. A 150 pound pig generates an average of 10.5 pounds of manure per day (ISUE, 1994a). The nitrogen and phosphorus content of animal manure is proportional to the solids content.

An anaerobic lagoon is an uncovered earthen impoundment, designed and operated to provide both long-term storage and partial treatment of animal wastes from a confinement feeding operation. The animal manure is treated with water which creates a greater volume of waste. Anaerobic lagoons are designed to reduce the nutrient content of manure through bacterial action. Methane, carbon dioxide, ammonia and hydrogen sulfide are by-products of this bacterial action. There are two common types of anaerobic lagoons in Iowa: single-stage and multi-stage (ISUE, 1994b). In multi-stage lagoons, the effluent produced in the first cell is transferred to the secondary cells, where further biological treatment occurs. In a single-stage lagoon, no secondary treatment occurs. The DNR rules require that a portion of the wastes be removed from the lagoon and disposed of by land application at least once annually. Liquid from the lagoon is land applied while the sludge remains at the bottom of the lagoon. The nutrient content of the manure is less than for an earthen basin, therefore a greater volume of manure can be applied per acre relative to an earthen basin.



**Figure 2.** Map shows the distribution and size, by landform region, of the permitted hog confinement facilities. The facilities represent only those sites that required a permit from the DNR and were permitted from 1987 through December 1997. The number of hogs at each site is based on the live animal weight divided by 150 pounds. (Source: Iowa Department of Natural Resources.)

An earthen basin is an uncovered impoundment designed and operated to provide short-term storage of wastes from a confinement feeding operation. Basins are not designed to provide treatment of the animal waste. Unlike lagoons, a minimal amount of water is added to basins. The DNR requires that all wastes be removed from the basin at least two times a year and disposed of by land application. By design, earthen basins hold six to eight months of waste production and minimize the loss of nutrients in the manure. Before manure from a basin can be applied, the solids that have settled to the bottom of the basin are agitated to provide a uniform consistency to the manure. Manure from an earthen basin requires a greater land base for application because of the high nutrient content of the manure relative to a lagoon. The cost to dispose of the manure from a basin is higher compared to a lagoon. As a safety measure, both basins and lagoons can be filled to within no less than two feet of the top of the structure in order to maintain a minimum of a 2-foot freeboard.

Total nitrogen values vary for manure stored in an earthen basin versus an earthen lagoon. It is estimated that during a one-year storage period of manure in a lagoon, 60-70% of the nitrogen is lost from the manure and 80% of the phosphorus remains at the bottom of the lagoon as sludge (ISUE, 1994a). As a general rule of thumb, hog manure stored in an earthen basin has a nutrient value of 36 pounds N/1,000 gallon of liquid manure compared to 3 pounds N/1,000 gallons of liquid manure stored in an earthen lagoon (MidWest Plan Service, 1985). Construction costs and the time required to manage a lagoon is

high compared to an earthen basin, whereas, the land required to apply the manure and the cost involved in disposing of the manure is low for the lagoon relative to an earthen basin.

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## **STOP 5. GROUNDWATER MONITORING TRENDS AT AN EARTHEN MANURE-STORAGE STRUCTURE**

Deborah J. Quade, Robert D. Libra and Lynette S. Seigley

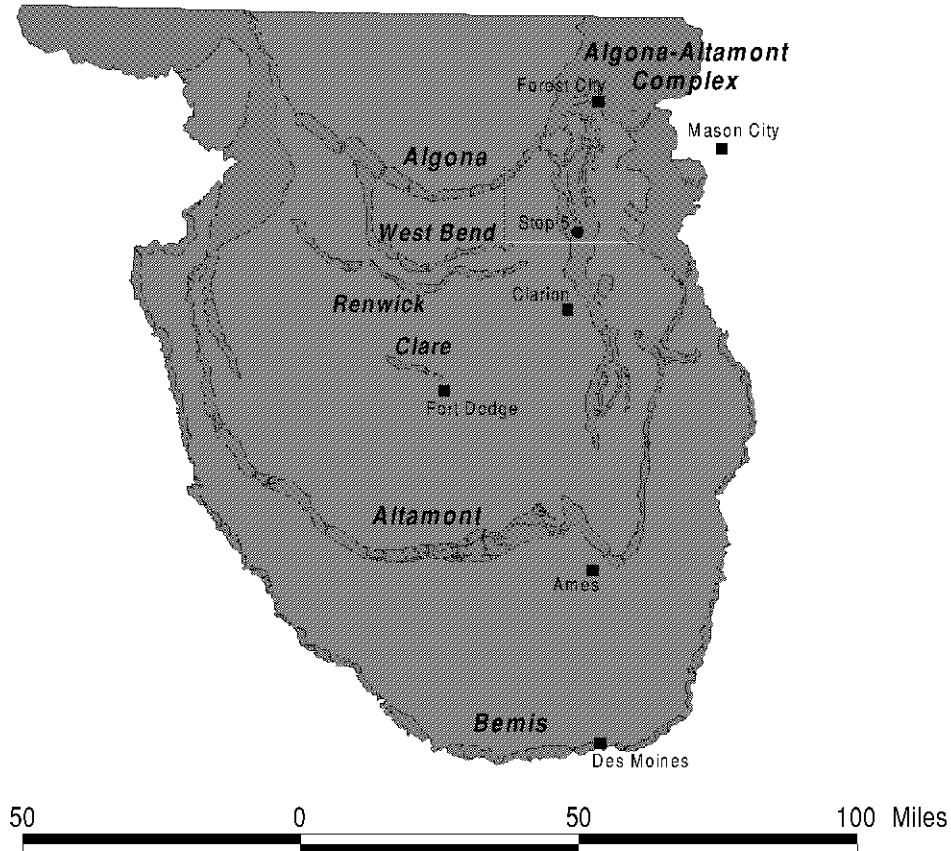
### **INTRODUCTION**

During the 1990s, a number of large-scale hog confinement operations were constructed in Iowa. The majority of these large animal confinement operations (ACOs) utilize earthen structures (basins or anaerobic lagoons) to store manure until it can be land applied to crops. In 1993, the Iowa Department of Natural Resources-Geological Survey Bureau (GSB) completed site investigations and began monitoring shallow groundwater quality at three recently built earthen manure-storage (EMS) structures. These units were typical of ACOs currently being constructed and used in Iowa for concentrated hog production. These sites were selected from areas with differing surficial geologic materials: the Des Moines Lobe (DML) in north-central Iowa, the Iowan Erosion Surface (IES) in east-central Iowa, and the thick loess region of western Iowa. Three to seven shallow (<25 ft.) monitoring wells were installed around each structure. Presently, GSB staff are taking water levels measurements and water samples are collected quarterly for nitrate-N, ammonia-N, fecal coliform bacteria, chloride, total organic carbon, sulfate, phosphate-P, and other ions.

To date, seepage has been detected at the DML and IES sites. Indications of seepage are similar and include: the decline or loss of nitrate-N and sulfate, and an increase in concentrations of chloride and total organic carbon. Fecal coliform bacteria have been sporadically detected at all wells at the DML site. Concentrations of nutrients, such as ammonia-N, initially did not increase, indicating these species were being retained by cation exchange. However, ammonia-N concentrations have recently shown increases in berm wells at the DML and IES sites suggesting the exchange capacity is being exceeded. Organic-N concentrations have increased, and are typically higher than ammonia-N concentrations. Exchange reactions that limit ammonia-N transport result in a build-up of ammonia-N beneath an EMS structure. At the allowable seepage rate of 1/16<sup>th</sup> inch/day, a basin similar to the DML site (4,500-head hog finishing operation) would add approximately 5,300 pounds of ammonia-N to the glacial materials beneath the ½-acre basin annually.

### **LIVESTOCK WASTE HANDLING SYSTEM—A SUSTAINABLE APPROACH**

The DML site is located in southern Hancock County, on the Des Moines Lobe (Figure 1). The owners of this facility operate a 4,500-hog finishing operation and farm 370 acres, primarily in a corn and soybean rotation. An earthen basin is used to store the manure from the hog operation. Very little biologic treatment of manure occurs in an earthen basin, thus preserving much of the nutrient content of the manure. Slurry samples collected from the earthen basin in December 1994 contained 840 mg/L chloride, <0.1 mg/L nitrate-N, and 2200 mg/L ammonia-N and reflect the higher nutrient value associated with earthen basins relative to lagoons. The operators of the DML site view the manure as a resource and apply it as a fertilizer to their available land base, thus reducing their purchase of commercial fertilizer.



**Figure 1.** Location of the Hancock county and the DML site with respect to former ice margins on the Des Moines Lobe in Iowa.

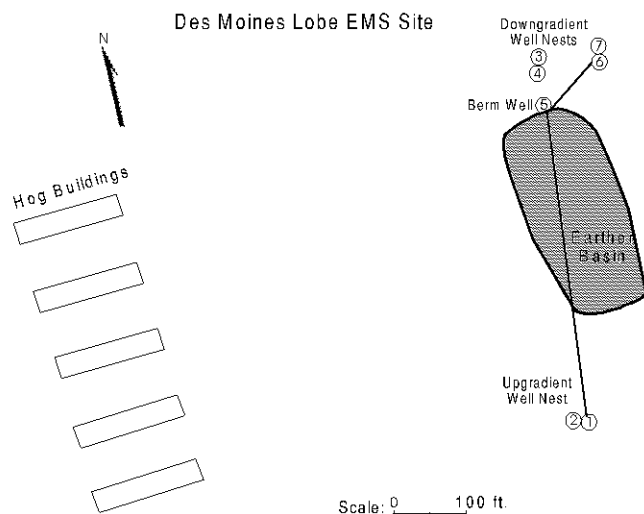
The earthen basin is constructed of locally derived materials, primarily supraglacial stratified diamicton, Dows Formation--Morgan Member. The Morgan Member is characterized by low bulk density values and variable textures, which vary from loam, to sandy loam to sand textures. To meet state requirements, the earthen basin is designed to limit seepage to no more than 1/16 inch/day and to hold manure for up to 240 days. The lagoon has a capacity or total storage of 250,000 cu ft. or approximately 1.6 million gallons of manure. Manure is pumped out of the earthen basin twice a year, in late April and late October. On average, ~900,000 to 1 million gallons is pumped each time. Water levels in the downgradient berm well reflect these pump-out periods, as they decline following the pump out. The pumped slurry is applied by a custom applicator who uses an “umbilical cord” injection system. With the “umbilical cord” method, manure is pumped directly from the earthen basin through a hose to a tractor unit in a field adjacent to the earthen basin. The tractor unit directly injects the manure a few inches below the surface. Manure is continually pumped as the tractor moves across the field. The farm operators estimate that 8,000 to 10,000 gallons of manure per acre are applied during application. Manure is not applied within 20 to 25 feet of the monitoring wells and within 50 feet of surface intakes.

The operators of this facility utilize a crop consultant to soil sample the nearby fields to determine the nutrient needs of the fields where the manure will be applied. The consultant prepares a grid map of the farm showing the levels of P, K, and N currently available. This grid map allows the custom applicator to modify application rates of manure to a field to place additional manure where soil nutrient levels are low or reduce manure rates where nutrient levels are high. At this site, the operators calculate manure applications based on established yields for corn of 145 to 150 bushels per acre rather than target yields

which may represent unrealistic yield goals. It costs an estimated \$6,500 per application (\$13,000 a year) to use the “umbilical cord” injection method. It is estimated that the fertilizer value of this manure is \$20,000-\$21,000 on an annual basis. Despite the high costs of custom application, the operators estimate that they save \$7,000-\$8,000 a year in fertilizer costs and receive added benefits by utilizing a more environmentally-friendly application method.

## MONITORING WELL DESIGN

In December 1993, GSB installed seven monitoring wells around the earthen basin. Two wells were nested upgradient of the earthen basin, one well was installed through the berm wall of the earthen basin on the downgradient side, and four wells were installed in two well nests downgradient of the earthen basin (Figure 2). The wells were constructed of 1-1/2 inch PVC pipe with 5-foot, 0.01 slot-size PVC screens. The wells range in depth from seven to twenty feet. Polyethylene tubing, 1/4” in diameter, was dedicated to each well and installed in the well by drilling an angled hole in the well casing wall. Samples are drawn from the wells using a vacuum hand pump. Several well volumes are drawn from the wells prior to sample collection.



**Figure 2.** Diagram of the DML site showing the location of the storage basin, monitoring wells, and hog buildings.

Several well volumes are drawn from the wells prior to sample collection.

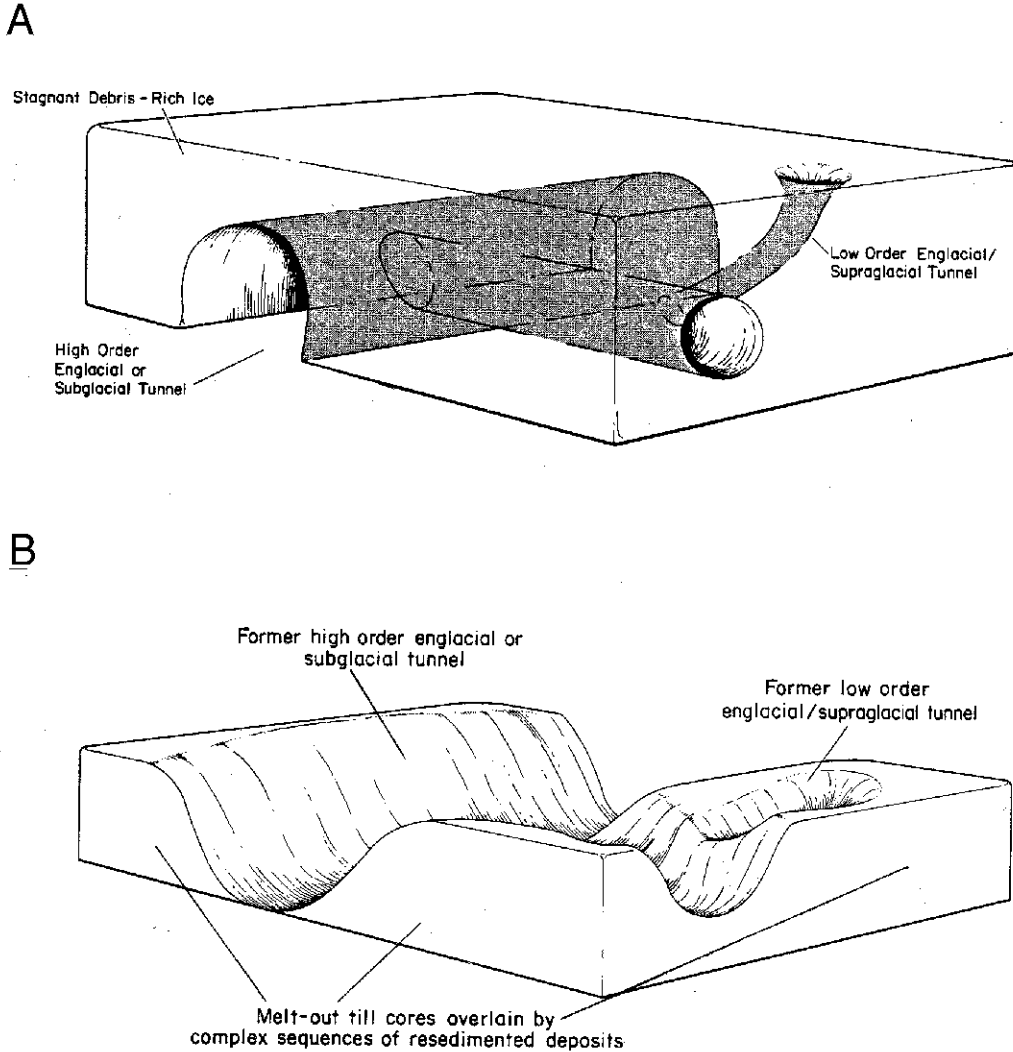
## HYDROGEOLOGIC SETTING

The geologic setting of the Des Moines Lobe (DML) is a complex upland landscape composed of glacial deposits that comprise the Dows Formation in Iowa. Various landform types are present on the DML and differing sequences of underlying glacial deposits are associated with these landforms. It is important to recognize various landscape types, the location of these landforms and their underlying sediment sequences in order to evaluate the suitability of site locations on the DML.

Important glacial landscape features of the DML are linked-depression systems. It is now recognized that linked-depression systems are not confined to former ice marginal areas where they are most dense and recognizable but that linked areas extend across the entire DML and are regional in scale and associated with each advance of the DML (Bettis et. al., 1996). Linked-depression systems are associated with upland as well as drainage landforms of the DML. These recently recognized systems (Kemmis, 1991) consist of a series of semi-closed depressions that have one or more “outlets” across low saddle-like areas (Figure 3). The saddles separate a chain of depressions that define a valley. The formation of linked-depression systems is interpreted to occur as a glacial karst system developing in a debris-rich stagnant glacier. As the ice slowly melted, tunnels within the stagnant glacier functioned as an internal drainage network. Eventually, these tunnels became clogged with stratified deposits of silt, sand, and gravel, and then were covered with poorly sorted sediments that either melted out from the overlying ice or were transported by mudflows and streams on the unstable surface of the disintegrating glacier. Shallow, porous sand and gravel bodies now occupy the former glacial tunnels and function as subsurface links be-

tween modern-day, semi-closed depressions on the land surface and successively larger surface-drainage routes (Figure 4).

The DML site is located in the uppermost reaches of a linked-depression system that connects the hummocky uplands of the Altamont Moraine Complex with the West Branch of the Iowa River (Figure 5). Linked-depression systems most likely serve as a relatively high permeability, preferential pathway

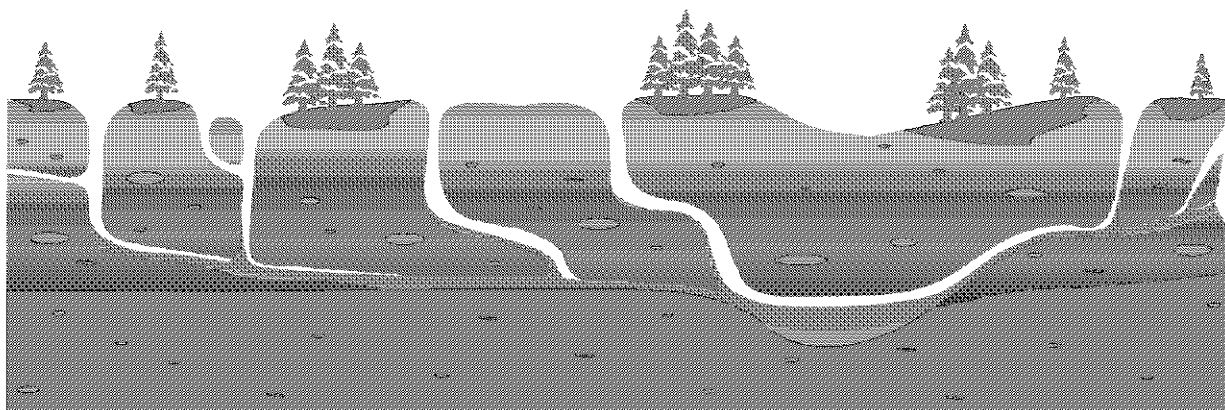


**Figure 3.** A model for the development of present-day Des Moines Lobe topography. The glacial karst system with low-order (smaller) tunnels connecting to high-order (larger) tunnels within and at the base of the stagnant glacier (Kemmis, 1991).

for shallow groundwater movement. These systems are complex features that serve as an “interconnected” drainage network linking hummocky uplands (moraine areas) to nearby streams and rivers. However, the discontinuous nature of the sand and gravel bodies, and the presence of minor topographic “saddles” between individual depressions complicate the hydrologic role of linked areas.

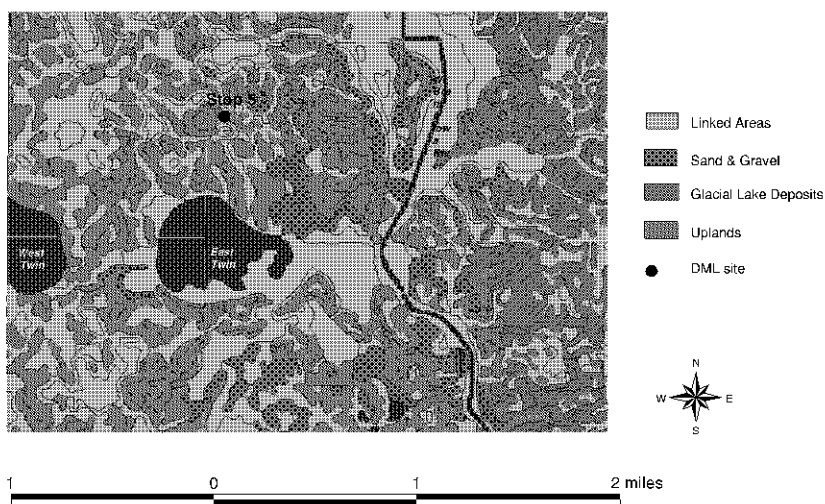
## STRATIGRAPHY

Figure 6 illustrates the stratigraphic sequence exposed in the drilling transect at the DML site. In this area, the Dows Fm. is mantled with undifferentiated Holocene-age sediments of the DeForest Fm. The DeForest Fm. varies in thickness from <1 meter on the uplands to over 2.5 meters in the drainageways. The Dows Fm. consists of two different glacial tills the Morgan and Alden members. The Morgan Member, a less dense, variably textured till formed by mudflows, debris flows, and flowing water at the surface of the ice. The Morgan Member also contains continuous to discontinuous sand, gravel and silt deposits that accumulated in the former glacial karst system draining the stagnant glacier. Sediment depos-



**Figure 4.** A cross-section through the stagnant Des Moines Lobe glacier illustrates a glacial karst system. A network of drainage tunnels is present within and at the base of the stagnant glacier. A few of the larger tunnels will eventually become major river valleys.

ited beneath or at the base of the glacier is a uniform, massive, dense loam textured, slowly permeable, subglacial till called the Alden Member (Figure 7). The well transect at this site is representative of a part of the linked-depression system which developed within the ice; sand and gravel bodies are discontinuous across the depression axis. In this moderate relief hummocky area, the Alden Mbr. forms the cores of the hummocks, while the Morgan Mbr. sediments flank the lower side slopes of the hummock and extend into the drainageway. The stratigraphic sequence described at this site is similar to the stratigraphy

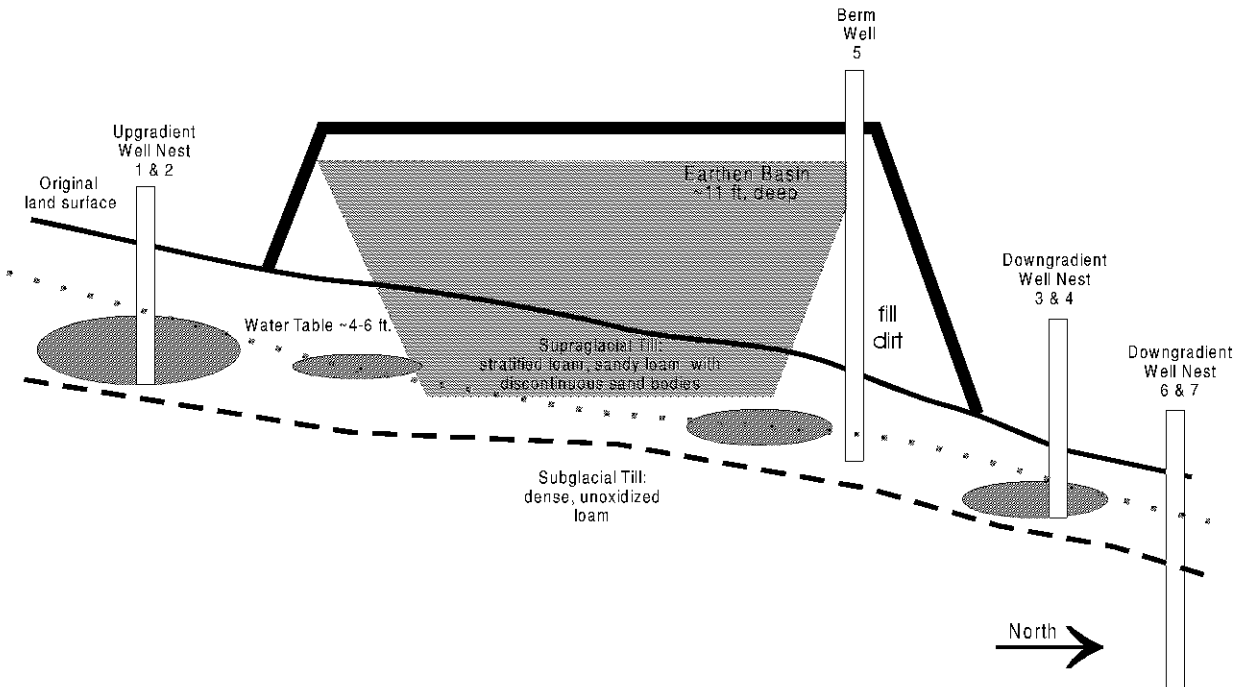


**Figure 5.** Preliminary susceptibility assessment of the digitized soil survey for a portion of T. 94N., R. 24W. in Hancock County using existing geologic information and Geographic Information System analysis. Map shows a highly susceptible area with pervasive linked drainages in a moderate- to high-relief landform area (Altamont ice margin complex) and the location of the DML site (Stop 5).

described in the upper reaches of a linked-depression system in a Humboldt County in an area that is not a former ice marginal area (Bettis et al., 1996).

## WATER QUALITY RESULTS

Background samples were collected from the monitoring wells in January 1994, prior to the filling of the basin. Concentrations of nitrate-N, chloride, and sulfate in six of the wells were relatively uniform, ranging from 15-20 mg/L NO<sub>3</sub>-N, 18-35 mg/L chloride, and 24-38 mg/L sulfate. The relatively uniform



**Figure 6.** Illustration of the earthen manure-storage structure at the DML site after construction and monitoring well placement. Note the regionally high water table and the presence of porous sand and gravel bodies within the Morgan Member till that may function as preferential pathways linking shallow groundwater with surface waters. Also, note the water table is below the floor of the basin at the beginning of the study.

concentrations of these ions, and the relatively high NO<sub>3</sub>-N concentrations, result from the long history of row-crop agriculture on the land where the basin was built. Background values from the Kan-6 well, which is the only well fully completed in the Alden Mbr., were much different than the other six wells. Nitrate-N was lower (<1 mg/L), while chloride (40 mg/L) and sulfate (94 mg/L) values were higher than concentrations from the other six wells at this site. The lack of nitrate at this well suggests denitrification occurs within the unoxidized Alden Mbr. sediments.

Grab samples of the waste liquid have been collected three times since 1994. Chloride concentrations are relatively consistent, from 840-1,100 mg/L; ammonia-N concentrations are more variable, ranging from 2,200-4,400 mg/L; nitrate-N concentrations are negligible; and phosphate-P concentrations were determined once, and were 200 mg/L. The differences in concentrations are variable and are likely to change with time for a variety of reasons (Westermann et al., 1993).

Varying indications of seepage from the basin have been detected at all downgradient wells. Figure 8 shows pertinent monitoring results from Kan-5, which samples the groundwater immediately after it has passed beneath the basin. Indications of seepage include increases in the concentrations of chloride and total organic carbon (TOC), and a sharp decline in nitrate-N and sulfate concentrations. Chloride concentrations began increasing about three months after the basin began receiving wastes, reaching 400 mg/L after three years. A mass balance based on the highest chloride concentrations indicates the water sampled at Kan-5 was a mixture of about 55% groundwater and 45% basin seepage. Chloride concen-

STRATIGRAPHY

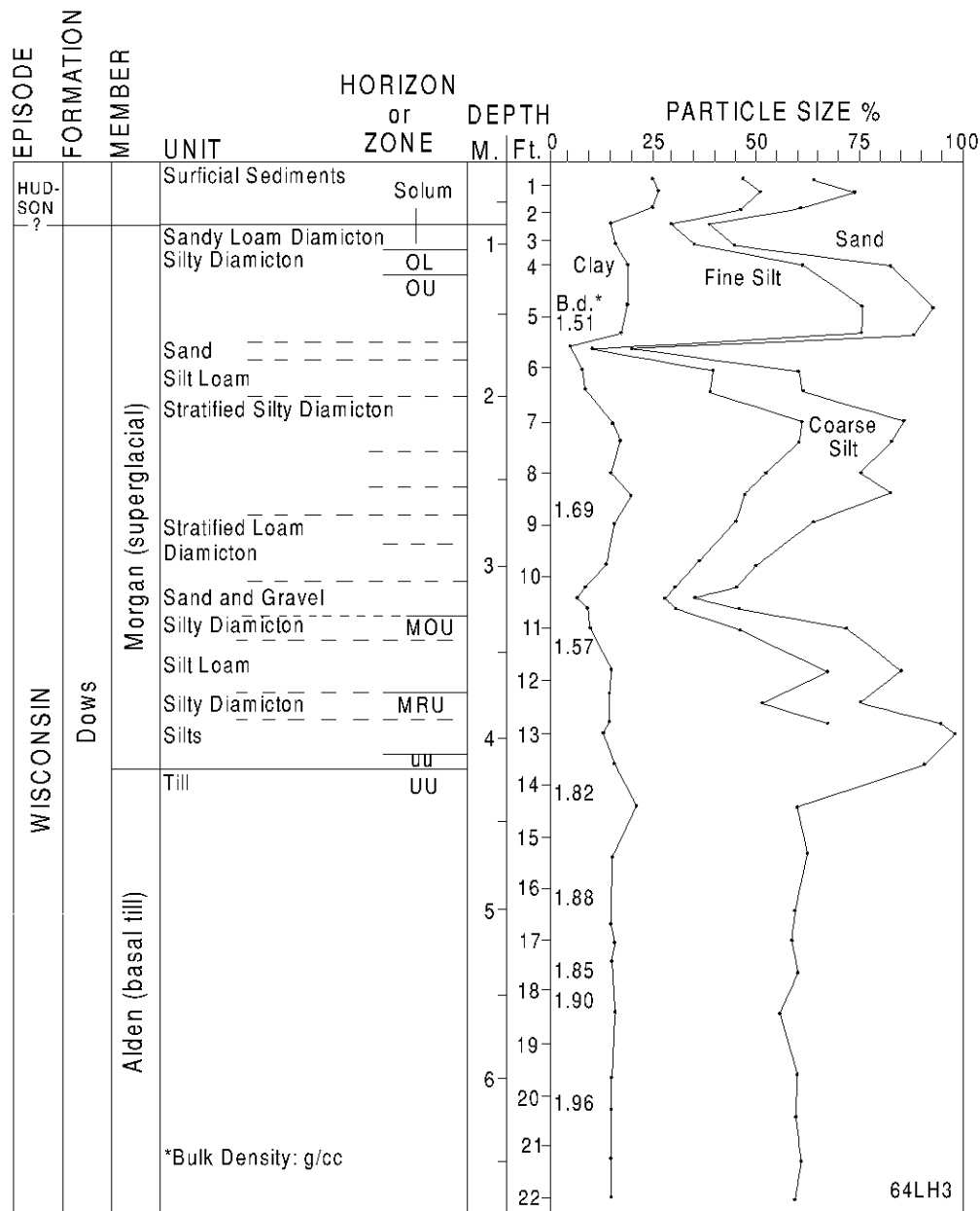
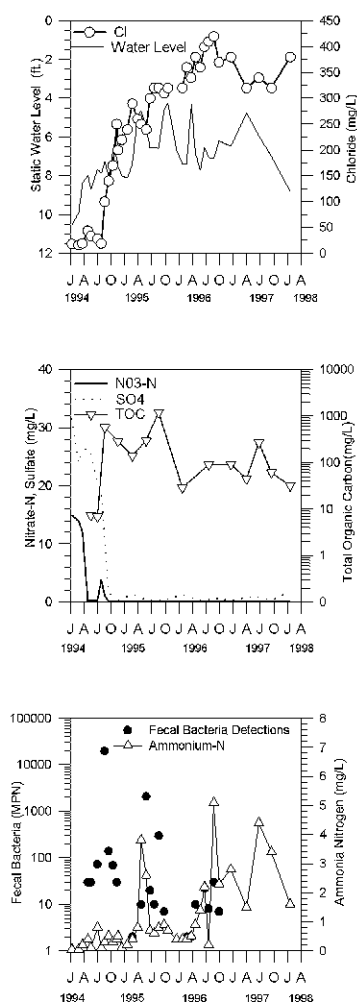


Figure 7. Stratigraphic, particle-size, and bulk-density data from a core site on the Des Moines Lobe. Properties of two types of glacial till are shown.

trations then declined to about 325 mg/L before increasing again. The continuing high chloride concentrations indicate the manure has not “sealed” the basin (Barrington and Jutras, 1983; Miller et al., 1985; Rowsell et al., 1985).



**Figure 8.** Monitoring results from the berm well (Kan-5) at the DML site.

largely retained below the basin, concentrations appear to be increasing over time. This suggests the adsorptive or cation-exchange capacity of the glacial materials beneath the structure is being exceeded, and that further increases in ammonia-N transport to Kan-5 will occur. Organic-N concentrations have occasionally been measured, and routinely exceed ammonia-N concentrations.

The farthest downgradient well nest (Kan-6, Kan-7) at the DML site is located about 150 feet from the basin. Water-quality trends for Kan-6 and Kan-7 are similar to those found at Kan-5, but seepage-related changes are less significant. Water quality trends at the Kan-7 well are similar to those at the “berm” well—a decline in nitrate-N and sulfate concentrations and an increase in chloride concentrations (Figure 10). However, a mass-balance based on chloride suggests the groundwater passing approximately 150 feet from the basin contains only 15% seepage. At this time, transport of ammonia-N and phosphate

TOC concentrations at Kan-5 increased from less than 10 mg/L to over 200 mg/L during the summer of 1994, and have varied from 30 mg/L to over 1,000 mg/L since then. There appears to be a seasonal trend to the data, with higher concentrations occurring in the summer. The decrease in nitrate-N and sulfate concentrations is a result of denitrification and sulfate reduction, respectively, generated by the anaerobic, organic-carbon rich nature of the seepage from the basin. Fecal coliform bacteria were present in 21 of the 34 monthly samples collected. Concentrations between 10 and 100 colonies/100 ml are most common, and are higher during summer, which suggests the bacteria are surviving longer, and are more likely to be transported to Kan-5, under warmer conditions.

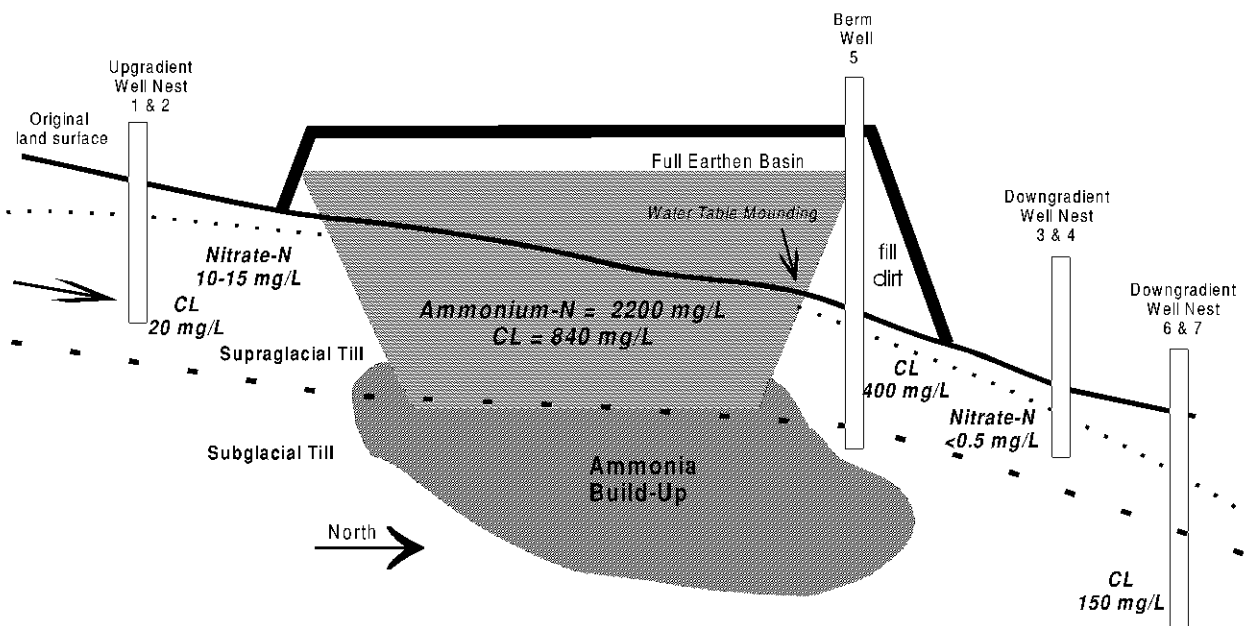
While the chloride data from Kan-5 clearly show the basin is seeping, the major nutrients ammonia-N and phosphate-P (and presumably potassium) have not shown a similar response. Total phosphate-P concentrations have remained below the 0.5 mg/L detection limit. Ammonia-N concentrations have ranged from near zero to about 5 mg/L, but have often been below 1 mg/L. If ammonia-N and phosphate-P were being transported from the basin as effectively as the conservative ion chloride, water from Kan-5 would likely contain over 1,000 mg/L ammonia-N and 100 mg/L phosphate-P. This indicates these nutrients are largely being retained, via cation-exchange processes, on the clayey materials below the basin. A considerable build-up of nutrients may be occurring below the basin, depending upon the actual volume of seepage. For perspective, the maximum allowable seepage rate for earthen waste structures in Iowa is 1/16<sup>th</sup> inch/day. If the DML basin were seeping at the legal limit, roughly 5,300 pounds of ammonia-N would be retained on the glacial materials beneath the ½-acre basin each year (Figure 9). While ammonia-N is



has not occurred at any of the downgradient wells, suggesting the ammonia build-up under the basin is being retained.

## DISCUSSION

Seepage of waste fluid to the water table is occurring at two of the three EMS structures being monitored by GSB. Indications of this seepage are generally similar at all affected monitoring wells, and include rising concentrations of chloride and organic carbon, and declining concentrations of sulfate and nitrate. Recent observations have noted increasing organic-N concentrations. Concentrations of nutrients



**Figure 9.** Illustration of the earthen manure-storage structure at the DML site and more recent trends in shallow groundwater quality. Note the water table is now well above the basin floor and appears to be mounding in response to seepage through the berm walls and floor.

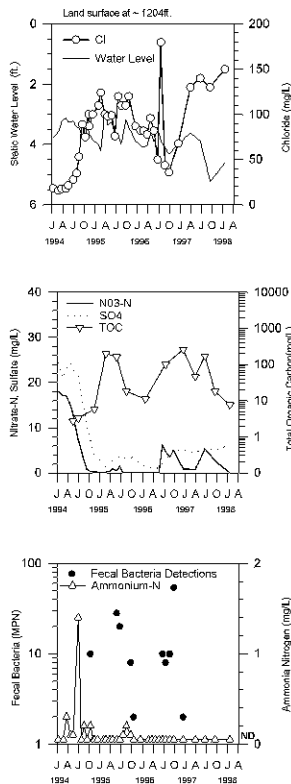
such as ammonia-N and phosphate-P have not significantly changed from background conditions until the latter part of the monitoring period; it appears that adsorption of these nutrients has largely removed them from the seepage. However, the nutrients could be remobilized under different geochemical conditions, and therefore remain a potential source for future contamination. Movement of fecal coliforms from the structures does not seem significant. The structures where seepage is readily identified (the DML and IES sites) have not sealed during four years of operation.

A number of previous studies have attempted to evaluate the effects of EMS structures on groundwater quality. Parker and others (1994) offer a comprehensive review of the literature on the topic. Most of these studies were conducted in areas with relatively permeable, coarse-grained surficial deposits. EMS structures built in such environments have been shown to cause increased concentrations of chloride and nutrients, such as ammonia-N (which may convert to nitrate-N), phosphorus, potassium, and other waste constituents in nearby shallow groundwater (Ritter et al., 1984; Sewell, 1978; Westerman et al., 1993). The permeable deposits described in these referenced studies allow for greater rates of seepage and groundwater flow than the more loamy glacial deposits beneath the Iowa structures, and additionally, have little cation exchange capacity. Therefore, it appears that ammonia-N and other cations are not significantly retained in earthen storage structures constructed in predominately coarse-grained materials.

**FINAL NOTE**

The results discussed above are from only three of the over six hundred permitted earthen manure-storage structures that have been constructed in Iowa in the last seven years. The monitored structures are relatively new, having been in use four years or less and are associated with "moderately-sized" operations that have been constructed on predominantly fine-grained, loamy materials. How typical the results of this investigation are is unknown. A number of factors must be considered in evaluating potential

seepage issues associated with EMS structures: engineering design, nature of materials, size of earthen structures and length of time that structures have been in operation. It is anticipated that these factors may yield quite different results when evaluating trends in seepage from EMS structures.



**Figure 10.** Monitoring results from the downgradient well (Kan-7) at the DML site.

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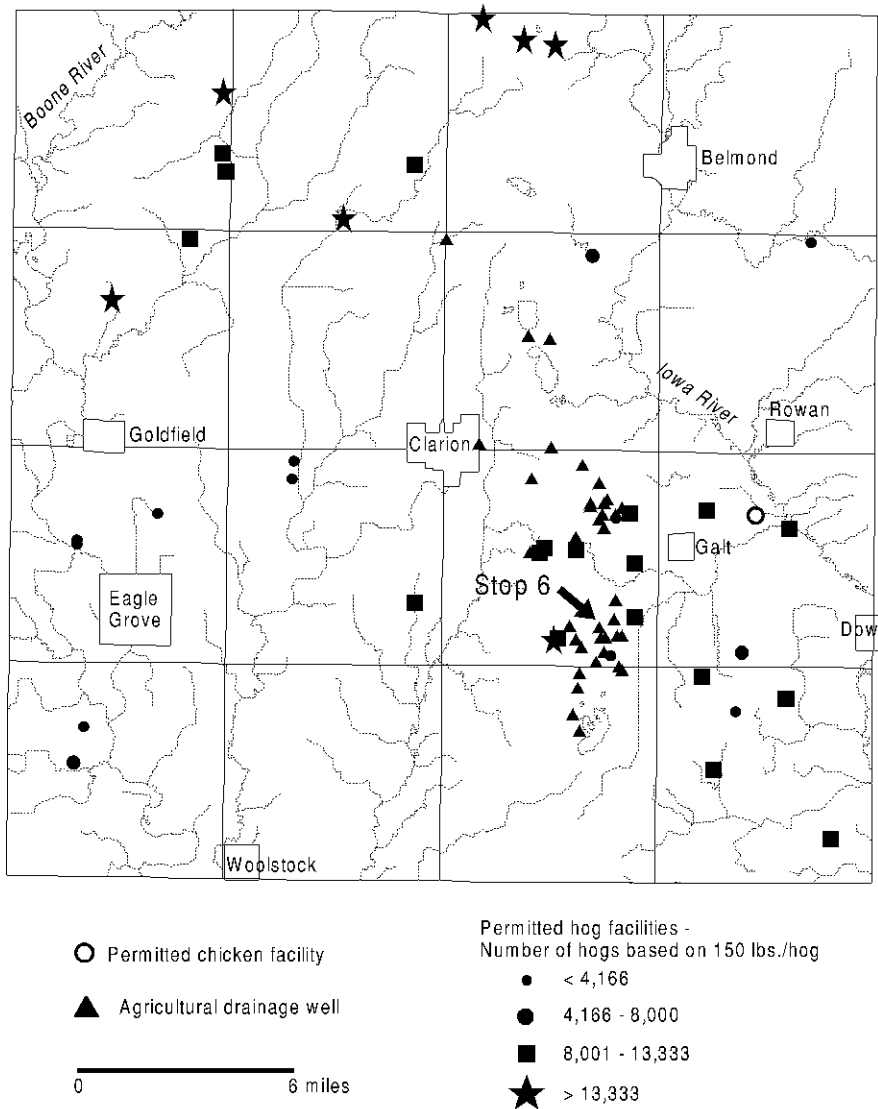
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## STOP 6. AGRICULTURAL DRAINAGE WELLS IN WRIGHT COUNTY

### PART I. GEOLOGIC SETTING

Lynette Seigley and Deborah J. Quade, Iowa Department of Natural Resources – Geological Survey Bureau



**Figure 1.** Location of permitted hog and chicken confinement facilities and agricultural drainage wells in Wright County.

Figure 1 shows the location of permitted hog confinement facilities and known active agricultural drainage wells (ADWs) in Wright County. The hog confinement facilities were permitted by the Iowa Department of Natural Resources (DNR) from 1987 through December 1997. The known active ADWs that exist in Wright County are based on the current database of DNR that is being used to identify the status of ADWs in Iowa. There are an estimated 38 active ADWs in Wright County, and known depths range from 80 to 265 feet. Several ADWs have surface-water intakes. Most of the ADWs in Wright County are located in Lincoln, Grant, and Wall Lake townships.

The majority of the ADWs in Wright County are located on an upland plain characterized by low relief with a few diffuse circular ridges. This upland plain contains

soils of the Brown-ton-Ottosen-Bode Association, which are heavy textured, very gently sloping to level, and are developed in lacustrine sediments (Lake Mills Mbr. of the Dows Formation; 0.5 - 2 m thick) over undifferentiated diamicton of the Dows Formation (Kemmis et al., 1981). This soil association is poorly drained to somewhat poorly drained. Most areas underlain by this association are drained by tile and surface outlets. The majority of ADWs in Wright County are located in areas where this soil association is

mapped. This low relief, poorly drained area of lacustrine sediments also marks the location of Glacial Lake Wright (Kemmis, 1991). This lake plain is bounded on the east (Highway 69) by a ridge that forms the backslope of the Altamont Moraine.

The Wright County glacial deposits are underlain by Mississippian-age bedrock, mostly carbonates of the Maynes Creek and Gilmore City formations (Woodson and Bunker, 1989). This bedrock serves as the primary aquifer used by rural residents and many small municipalities in the county. No regionally extensive confining units in the Mississippian bedrock occur in this area. Over 100 feet of Quaternary deposits, including the lacustrine sediments, overlie the Mississippian bedrock in the area where the majority of ADWs are located. The relatively thick cover of Quaternary deposits provides protection to the Mississippian aquifer from surficial contamination that is delivered by natural processes. In areas where ADWs are located, this protection is bypassed as tile water and surface water are injected directly into the underlying Mississippian bedrock aquifer.

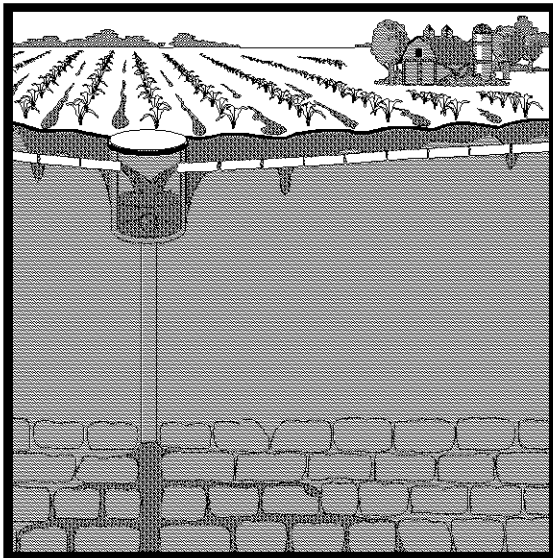
## PART II. AGRICULTURAL DRAINAGE WELL POLICY

Susan K. Heathcote, Iowa Environmental Council

As a result of the last glacial advance in North America, portions of the upper midwest were left with regions of very flat topography dotted with wetlands. Settlers soon found that if this land could be drained of excess water, very productive crops could be grown on the fertile landscape.

Subsurface drainage tiles are used extensively in Iowa to drain soils of excess moisture. In most areas of the state, this water drains to surface streams or drainage ditches. In some flat areas where an integrated natural drainage system is lacking, landowners use agricultural drainage wells (ADWs) as the drainage outlet. These wells drain an estimated minimum of 40,000 acres in north-central Iowa, with the majority of ADWs located in Humboldt, Pocahontas, Floyd, and Wright counties. Nearly all of these wells, which are drilled up to hundreds of feet into underlying bedrock aquifers, were constructed between 1900 and 1950.

### AGRICULTURAL DRAINAGE WELL IMPACTS



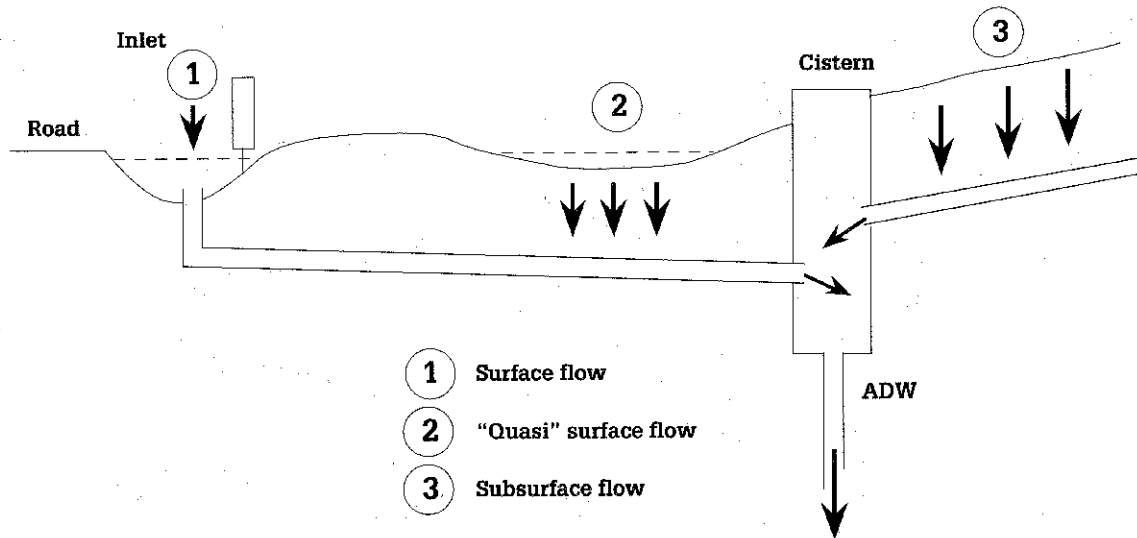
**Figure 1.** Schematic of an agricultural drainage well (ADW).

In Iowa, ADWs were generally finished into shallow, fractured carbonate aquifers with high transmissivity. This was done to assure adequate capacity and a minimum of plugging by any incoming sediment load. Figure 1 is a schematic of an ADW showing drainage tiles leading to a collection cistern that then drains to the aquifer through a drilled shaft. Most wells are less than 100 feet deep, but some wells range up to 400 feet in depth. Libra and Hallberg (1993) summarize the hydrogeologic settings and water-quality implications of ADWs in Iowa.

ADWs are direct routes for contaminants from the land's surface to enter the aquifer. Research has shown that ADWs increase contaminant concentrations, including pesticides, fertilizer, manure, bacteria, and sediment in the receiving aquifers. In addition, some private septic systems also have direct connections to tiles that discharge into

ADWs. This is a particular health concern because of the possible presence of human pathogens. The aquifers that receive this drainage are the same aquifers that provide water for drinking, agriculture, and business for thousands of people.

Figure 2 is a schematic of an ADW system that illustrates three types of drainage that are possible. The first is surface flow. Surface intakes are typically located in road ditches and natural depressions, allowing surface water to enter the wells directly. Many ADW systems provide drainage for roadways and road ditches as well as cropland. In general, chemicals, bacteria, and sediment are highest in drainage water from surface intakes.



**Figure 2.** Schematic of an agricultural drainage well (ADW) illustrating the three types of flow delivered to an ADW. (Source: IDALS, 1994.)



**Figure 3.** An ADW in Humboldt County, Iowa. The top of the cistern is in poor repair and has no cover. (Photo courtesy of the Iowa Environmental Council.)

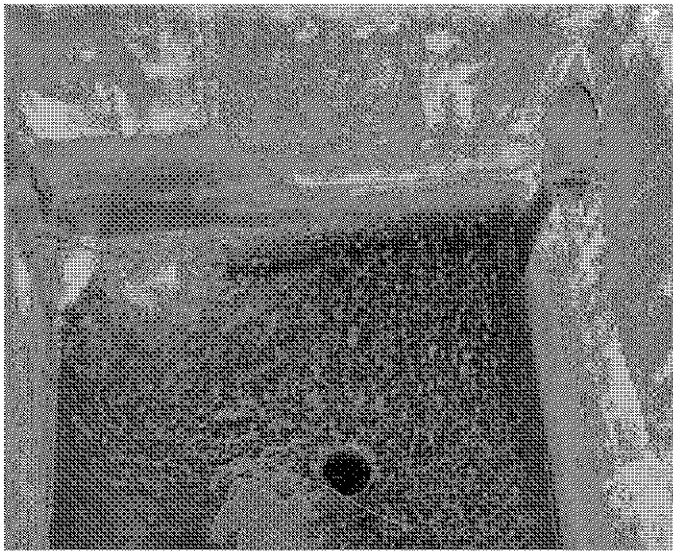
The second type of drainage is quasi-surface flow. When ponding of water occurs in low areas, water may travel through the soil profile through macropores and fractures. High levels of contaminants may be delivered into an ADW during wet periods.

The third type of drainage is subsurface flow that originates from runoff infiltration. Because of the filtering characteristics of the soil profile, there is a significant decrease in contaminants that enter the ADW. An exception is nitrate, which increases due to leaching from the soil profile. Nitrates in the subsurface drainage water often exceed the Environmental Protection Agency's drinking water standard of 10 milligrams per liter.

Figures 3 and 4 show photographs of two agricultural drainage wells in Humboldt County, Iowa. Both are located near the edge of farm fields along Highway 3, draining both the field and the roadway. Figure 3 illustrates the erosion that can occur from surface water flow into the ADW wellhead. The cistern is in poor repair and has no cover. This is the case for many ADWs in Iowa. The ADW in Figure 4 has an improvised cover -- an old piece of wood with a rock on top. Neither of these wells protect against direct surface water inflow at the wellhead or provide any security against unauthorized access.



**Figure 4.** An ADW in Humboldt County, Iowa. Note the large amount of standing water in the background. (Photo courtesy of the Iowa Environmental Council.)



**Figure 5.** The concrete cistern of an ADW in Wright County, Iowa. Tile lines deliver water to the cistern. The pipe in the lower center of the figure is the drilled shaft of the ADW that discharges water into the underlying Mississippian aquifer. (Photo courtesy of the Iowa Environmental Council.)

The cistern or upper casing of an ADW is generally constructed of poured concrete, metal culvert, large diameter clay tile, or grouted bricks. Figure 5 is a view looking down into the cistern of an ADW in Wright County.

## ADW REGULATIONS

It has been known for quite some time that agricultural drainage wells are a threat to the quality of our groundwater. The Environmental Protection Agency (EPA) has classified these drainage wells as “Class V injection wells” in the Underground Injection Control (UIC) Program. EPA states that “Class V wells are usually of simple construction and provide little or no protection against possible groundwater contamination.” According to federal law, all ADWs must be registered, although there are no penalties for not registering them.

ADWs have been recognized as a problem in Iowa for over 40 years (see Table 1). It was not until the 1987 Groundwater Protection Act (GWPA), however, that direct actions were taken to address this known threat to groundwater quality. One of the provisions in the GWPA was that all ADWs be registered with the state (this was in addition to the federal registration requirement). Wells that were not registered would not be eligible for any state financial assistance. In the 10 years that have followed the GWPA, research on continued use, as well as closure options, has been ongoing. Nearly 23 ADWs have been closed voluntarily in Floyd County (Moore, 1996), and another 25 were removed from the registration records because they had been incorrectly registered or were no longer functional due to siltation. The most recent inventory of



**Table 1. Chronology of the Agricultural Drainage Well (ADW) Issue in Iowa.**

1. Drainage wells were installed in north-central Iowa in the early 1900s, with installation reaching a peak during the 1940s and 1950s. No regulatory requirements existed for the installation of these wells.
2. In 1957, Iowa recognized the potential for contamination of groundwater supplies from these wells. A permit was required to construct new wells or to expand the drainage area of existing wells. A new well was permitted only if it could be shown that no pollutants would be discharged to groundwater. Wells constructed prior to 1957 were exempt from the permitting requirement.
3. From 1957 to 1982, the State issued only two permits for new ADW constructions.
4. Drainage entering four ADWs in Humboldt County were sampled from 1981-1983 as part of an Iowa State University research project by Baker and Austin (1985; Baker et al., 1985). Findings showed that 85% of the samples exceeded the nitrate health standard of 10 mg/l. Herbicides and insecticides were present in almost half of the samples, as well as sediment and bacteria. The researchers concluded that there is strong evidence that ADWs were increasing contaminant concentrations in groundwater aquifers.
5. In 1983, the state law was changed to require permitting of all drainage wells, regardless of the date of construction. Since permits were issued only if it could be shown that no pollutants would be discharged to the groundwater, and in light of the research showing the presence of pollutants in drainage water, no ADW permits have been issued since 1983.
6. Agricultural drainage wells are considered "injection wells" and are subject to regulation under the Underground Injection Control portion of the U.S. Safe Drinking Water Act. This regulation required registration of all ADWs with the Environmental Protection Agency (EPA) by June 24, 1985. A total of 230 ADWs in Iowa are registered with the EPA.
7. The 1987 Iowa Groundwater Protection Act (GWPA) established a goal to eliminate all groundwater contamination from ADWs by 1995, and required the following action:
  - All ADWs must be registered by January 1, 1988 (later extended to September 30, 1988).
  - Required the Iowa Department of Agriculture and Land Stewardship (IDALS) to set up a demonstration project to determine the types of practices which could eliminate groundwater contamination from ADWs. This study was also to examine alternative drainage methods.
  - ADW owners were required to submit a plan by July 1, 1991 showing how contamination would be eliminated from their ADWs (later extended to July 1, 1998).
8. As required by the GWPA, a total of 346 ADWs were registered with the Iowa Department of Natural Resources (IDNR). Merging of the EPA and IDNR registration lists, and elimination of structures incorrectly registered as ADWs, resulted in a combined registration list of 340 ADWs in Iowa.
9. A study conducted by IDALS from 1989 to 1993 evaluated four management alternatives for ADWs. Two alternatives involved ADW closure and two involved continued use. Based on study results, the IDNR is responsible for preparing rules for ADW continued use or closure.
10. A Floyd County groundwater protection project completed in 1996 resulted in the voluntary closure of 23 ADWs.
11. In 1997, an updated inventory of ADWs in Iowa was completed. ADWs closed in Floyd County and other wells incorrectly registered as ADWs or no longer functional were removed from the list. Currently, there are an estimated 292 active ADWs in Iowa.
12. An ADW bill (Senate File 473) was passed by the 1997 legislature and signed by Governor Branstad. This new law requires surface intakes to be removed from ADW systems, and for cisterns to be repaired and made watertight by December 31, 1998. This law also requires the closure of all ADWs located within the drainage area of earthen storage structures at permitted livestock confinement facilities by December 31, 1999. The law also prohibits new construction of earthen manure storage structures in areas which drain to ADWs. The legislature also appropriated \$3 million for fiscal years 1997 and 1998 for up to 75% cost share to provide alternative drainage assistance for landowners required to close ADWs. The bill also requires IDALS and IDNR to develop necessary rules by December 31, 1997.
13. Rules for the continued use aspects of the 1997 legislation were approved by the Environmental Protection Commission in December 1997, but final adoption has been postponed by the Administrative Rules Committee until May 1998, due to pending legislation which may affect the deadline for ADW repairs. The 1998 legislation proposes to postpone the repair deadline from December 31, 1998 to December 31, 2001.

ADWs in Iowa shows 292 active registered wells.

Other states also have ADWs, although many states do not have good inventories of wells and their locations. It is difficult to assess the status of ADWs in Iowa and other states because they are located mostly on private agricultural land, with little record of their installations. In many states regulation is non-existent.

An EPA inventory of ADWs indicates that 19 states have at least some known ADWs; nine states are known to have more than 10 wells. These nine states and the number of ADWs are Idaho (300), Iowa (292), New York (150), Texas (135), Arizona (111), Minnesota (56), Georgia (43), Wisconsin (23), and Michigan (15). EPA is currently completing a new nationwide survey of ADWs, and will be updating these inventory numbers.

ADW policy in other states ranges from ADWs being declared illegal and required to be closed when found, which is the case in North Dakota, to no policy at all at the state level, which is fairly common. Where states do not have an ADW program, EPA has authority over these injection wells. EPA will be issuing a guidance document in the near future on agricultural drainage wells (EPA, in press).

### HOG CONFINEMENT FACILITIES AND ADWS

Attention was focused on this issue in Iowa by the 1987 Groundwater Protection Act (GWPA). The GWPA led to increased research into alternatives to ADWs, however there were many barriers to implementing the recommendations from this research. In ADW areas, the main barrier to implementation was the cost associated with the alternatives – especially the cost of alternative drainage outlets necessary to continue farming if ADWS were closed. Outside of north-central Iowa, most Iowans were unaware of the existence of ADWs and the risk these wells posed to groundwater quality. There was, therefore, very little statewide support for the financial commitment necessary to implement ADW protections.

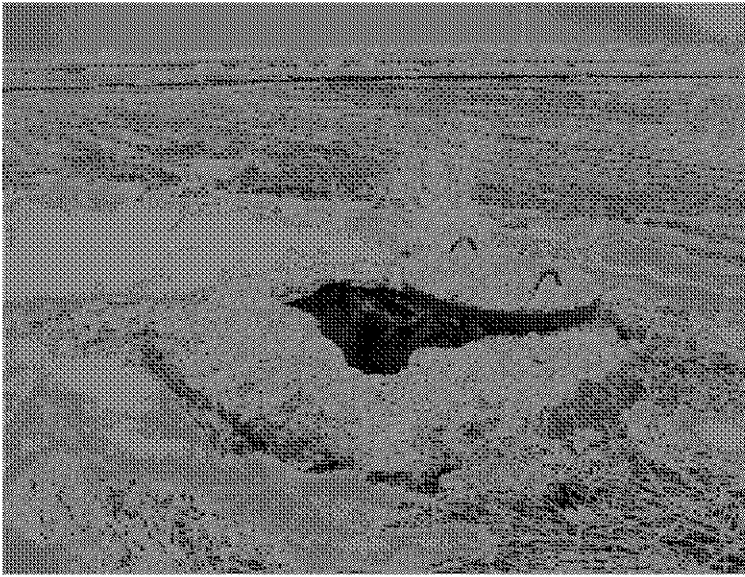
However, in the mid 1990s something changed. Large-scale confined animal feeding operations began expanding in Iowa and with them came multi-million gallon earthen manure storage structures. Many of the largest facilities were located in the ADW area of north-central Iowa (see Figure 2 in Seigley and Quade, *An Introduction to Hogs in Iowa*, this volume).



**Figure 6.** An agricultural drainage well located in Lincoln Township, Wright County, Iowa. In the background are several animal confinement buildings and the earthen lagoon associated with the facility. (Photo courtesy of the Iowa Environmental Council.)

The close proximity of large livestock confinement facilities to ADWs presented two main concerns: 1) impact to aquifers from surface drainage contaminated by runoff after land application of manure, and 2) risk of a catastrophic spill from a manure storage basin or lagoon entering an ADW.

These risks were particularly evident in Wright County where there are 46 large-scale permitted livestock facilities and 38 active ADWs (see Figure 1, Seigley and Quade, this stop). In Lincoln Township, just southeast of the town of Clarion, there are 12 permitted hog confinements and 28 ADWs. Including the area surrounding Lincoln Township, there are 27 ADWs within one mile of a permitted hog confinement facility. The Mississippian aquifer into which these ADWs drain is the main water supply for public and private water supplies in Wright County and much of north-central Iowa.



**Figure 7.** An agricultural drainage well located in Lincoln Township, Wright County, Iowa. This ADW is located in close proximity to several confinement facilities, including two 950,000-head chicken facilities, a 24,000-head finishing facility, and a swine nursery facility. (Photo courtesy of the Iowa Environmental Council.)



**Figure 8.** The cistern of the agricultural drainage well shown in Figure 7. (Photo courtesy of the Iowa Environmental Council.)

Figure 6 is a photograph of an ADW in Lincoln Township located down gradient from the large earthen lagoon of a hog confinement facility. You can see the tops of the confinement buildings along the horizon, peaking over the top of the lagoon berm. If this lagoon failed, or an undiscovered tile line ran below or near the lagoon, the natural drainage leads right to this ADW that drains to the aquifer below.

Figure 7 is a photograph of another ADW in Lincoln Township located in close proximity to several confinement facilities. In the background are structures that house 950,000 chickens (along the horizon to the right) and 24,000 finishing hogs (along the horizon to the left). Off the picture to the left are another 950,000 chicken

facility and a swine nursery facility. Figure 8 is a photograph looking down into the cistern of this well.

The ADW shown in this picture is just one of 13 ADWs in this area. As a quick expression of how much waste is produced in the vicinity of these ADWs, consider that one finishing hog is estimated to produce 3-4 times as much waste as a human. If you think of it in these terms, the finishing facility alone produces as much waste as a city of roughly 80,000 people.

### **1997 ADW LAW**

In response to concern about the risk posed by the juxtaposition of ADWs and large confinement facilities, the Iowa Environmental Council developed a strategy to focus attention on this issue.

In developing recommendations for new legislation, the Council worked closely with state agencies such as the Department of Natural Resources and Iowa Department of Agriculture and Land Stewardship, Division of Soil Conservation, to gather and analyze research information; policy makers including legislators and staff at the Governor's Office were consulted on necessary policy and legislative changes including funding; and partnerships were developed with key stakeholders such as the Animal Agriculture Consulting Organization (AACO), local farmers and landowners in ADW areas, and farm and commodity groups.

A critical element of the strategy was public education and building public awareness of the issue in order to develop a statewide constituency for action. This included working closely with our member organizations and the media. Communication of the issues with various groups, organizations, and agencies throughout the entire process was vital.

This joint effort helped create a statewide mandate which supported legislative leaders in creating solutions. The result was comprehensive legislation (Senate File 473) that addressed preventing pollution through ADWs. The main points of this comprehensive legislation are:

- Closure of ADWs at risk from nearby earthen manure storage structures. All ag drainage wells that are within a drainage area that includes a permitted earthen manure storage structure must be closed by December 31, 1999. This includes about 20 ADWs in Wright County.
- New construction or expansion of an earthen manure storage structure within an area that is drained by an ADW is now prohibited.
- Repair and improvement of ADWs in other areas is required for continued use. This includes removal of surface intakes and the repair and maintenance of cistern sidewalls to prevent surface water from entering the well. A locked cover must be added to prevent unauthorized access. The 1997 legislation set a December 31, 1998 deadline for these repairs, but legislation introduced during the 1998 legislative session may extend this deadline.

The Department of Natural Resources has proposed rules that will require ADW owners to obtain a permit for continued use. In order to receive a permit, ADWs must be repaired to meet the conditions of the 1997 legislation. In addition, landowners are required to remove all septic system connections to ADWs and to adopt best management practices on land that drains to ADWs.

The legislature has also set aside funds to assist the affected landowners. The state provides up to 75% cost-share for required ADW closures and for the costs associated with the development of alternative drainage to surface outlets. Federal Environmental Quality Incentive Program (EQIP) funds of up to 75% cost share are also available for cistern repairs, the removal of surface intakes and the installation of additional subsurface tile to maintain equivalent drainage for those wells that may continue to be used.

## REMAINING ISSUES

Although we have a good start, preventing pollution through ADWs is far from complete. The steps taken in the next few years will begin to lessen the affect that ADWs have on our groundwater. Key issues remain however. 1) How will we monitor ADWs and protect groundwater near earthen manure storage structures before the wells are closed? 2) What affect will a possible extension of the date for ADW repairs and surface intake removal have on the proposed permit process? 3) We have not determined how – or even if – we will require monitoring and inspections of ADW systems to assure groundwater protection where ADWs continue to operate. 4) We have not determined how we will identify and deal with unregistered ADWs. 5) Significant concerns remain regarding contamination of groundwater from pesticides, disease-causing microorganisms, and nitrogen.

Addressing this critical issue in Iowa and other states will require the continued involvement of concerned individuals.

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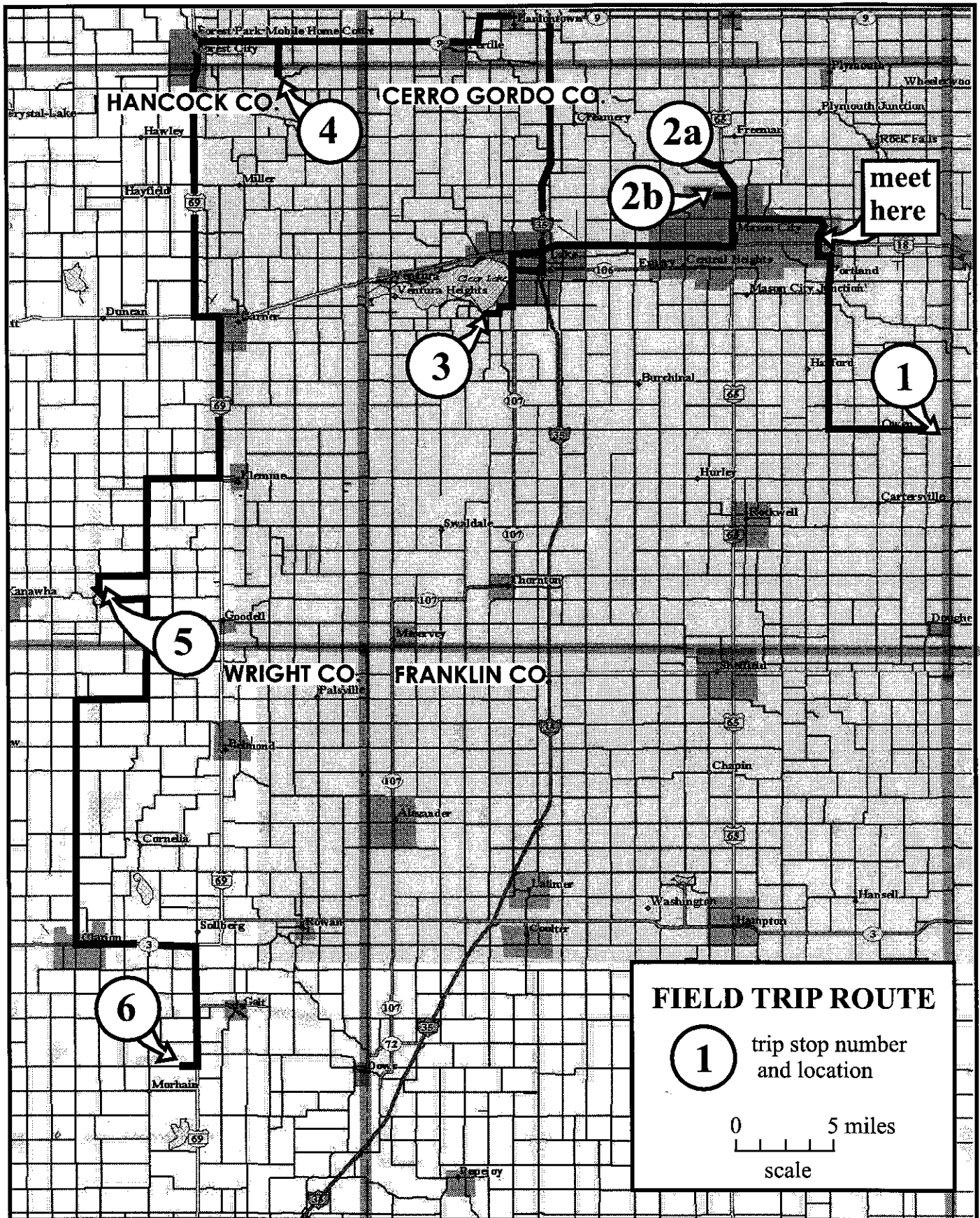
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HANCOCK CO.

CERRO GORDO CO.

WRIGHT CO.

FRANKLIN CO.

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**FIELD TRIP ROUTE**

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