Iowa Geology

1998

Number 23

COVER

The smooth, deeply creviced surface of the Fort Dodge gypsum beds results from groundwater movement along a series of intersecting vertical fractures in the soft gypsum. This surface is revealed during mining operations, when overlying glacial deposits are removed.

Photo by Ray Anderson

Iowa Geology

1998

Jean Cutler Prior—Editor

Editorial Committee
Raymond R. Anderson
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Bernard E. Hoyer
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Mary P. Skopec

Layout design by Patricia J. Lohmann

Geological Survey Bureau
109 Trowbridge Hall
Iowa City, Iowa 52242-1319
(319) 335-1575
http://www.igsb.uiowa.edu

Donald L. Koch
State Geologist and Bureau Chief

Iowa Department of Natural Resources
Larry J. Wilson, Director

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The meandering Des Moines River (left) joins the Mississippi River (right) at the southeastern tip of Iowa, near Keokuk. Though Iowa's land area accounts for only 5% of the Mississippi River basin, Iowa's streams supply almost 25% of the nitrate-nitrogen the Mississippi River delivers to the Gulf of Mexico. (Color-infrared photo.)

NITRATE NITROGEN
IOWA'S UNINTENDED EXPORT

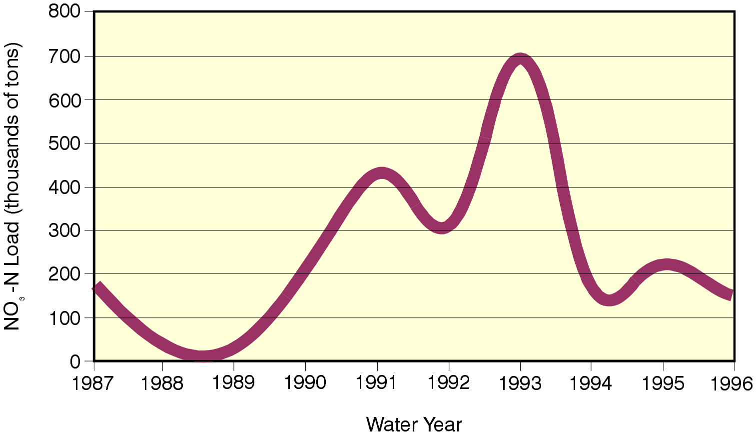
ROBERT D. LIBRA

The Mississippi River has long been an important transportation route for Iowa products. For decades, river barges have provided a relatively low-cost way to export the bounty from the state's farms, factories, and woodlands to the Gulf of Mexico and the world beyond. However, recent studies have highlighted an unintended export from Iowa and the rest of the Corn Belt to the Gulf, one that may be helping to generate a condition that limits the productivity of some of the Gulf's fisheries. This export is nitrogen, and the condition is called "hypoxia."

Hypoxia describes a zone of poorly oxygenated water that occurs along the Louisiana Gulf coast, and that may be growing more extensive. While the causes of hypoxia are still under debate, many marine scientists are convinced that an increase in the delivery of nutrients, particularly nitrogen, to the Gulf is at the heart of the problem. Nitrogen increases the production of tiny marine phytoplankton whose life cycle reduces oxygen available for fish and shrimp. Fish and shrimp populations decline in response to this less favorable environment.

The Mississippi River provides the bulk of the runoff to the Gulf, taking the drainage from 40% of the continental U.S. and funneling it southward. This impressive volume of water averages almost 140 cubic miles per year, enough to cover Iowa to a depth of 13 feet. It carries with it an equally impressive amount of nitrogen, estimated by the U.S. Geological Survey to average 1.65 million tons/year since 1980, with most of the nitrogen, about 1 million tons/year, in the form of the chemical compound nitrate (NO_3). When researchers look up-river for the sources of this nitrate, they find no shortage. The list of suspects includes human waste, industrial activities, and input from rain. However, most attention has focused on agricultural practices and sources, such as fertilizer, manure, legume production, and mineralization of soil nitrogen, all of which account for most of the nitrogen added to the Mississippi basin. The largest agricultural input occurs in the Corn Belt, and the greatest delivery of nitrate to the Mississippi River appears to be from Corn Belt states. Studies by the U.S. Geological Survey suggest that over 60% of the River's nitrate load is derived from sources north of St. Louis.

The possible link between hypoxia in the Gulf and nitrate from the Corn Belt raises questions about Iowa's



Estimate of Iowa's Nitrate-Nitrogen Export to the Mississippi River

nitrate export to the Mississippi. Estimating this contribution requires nitrate concentrations and stream flow rates for representative parts of the state which, when multiplied together, produce the total mass or load of nitrate. Two sets of monitoring data have been used to estimate loads for the period 1987-1996. The first data set includes weekly to bimonthly data from the Des Moines, Iowa, Cedar, and Turkey rivers, which together drain over 21,000 square miles, or 38% of the state. The average annual nitrate-N loads for the individual rivers are very similar, varying from 14 to 16 lbs/acre, with an overall average of 15 lbs/acre. This close correspondence suggests that 15 lbs/acre/year characterizes loads for the eastern part of the state as a whole. This load was adjusted downward when applied to drier western Iowa. Statewide, the results suggest nitrate-N loads from Iowa to the Mississippi River system averaged about 245,000 tons/year during the period. Additionally, these loads vary greatly year to year, ranging from 12,000 tons during the drought of 1989 to 700,000 tons during the floods of 1993 (see graph above). The average nitrate-N concentration for the Iowa rivers during the period was 5.6 mg/L. Both runoff and nitrate concentrations are greater in wetter years, resulting in the 50-fold variation in estimated N-loads between drought and flood conditions.

The second data set is provided by the DNR's surface-water monitoring network, which includes 13 smaller streams, with drainage areas of 400 to 1,200 square miles. These streams are distributed across the state and have been sampled monthly since 1987. Combining their nitrate-N concentrations and flow rates for 1987-1996 produces an average annual N-load of about 12.5 lbs/acre. The average nitrate-N concentration was 5.2 mg/L. If the loads from these streams characterize those that occurred statewide, an estimated 225,000 tons/year of nitrate-N was exported from Iowa during the period, ranging from 25,000 tons in 1989 to 655,000 tons in 1993. These amounts are remarkably similar to those estimated from the four larger rivers. Taken together, the estimates suggest that Iowa, on average, supplies almost 25% of the nitrate-N that the Mississippi River delivers to the Gulf of Mexico, while occupying less than 5% of its drainage basin.

What is the source of this unintended export? While all nitrogen sources contribute nitrate-N to the state's streams, 80% of Iowa's land is agricultural, and agricultural nitrate losses appear sufficient to account for the river loads. For example, nitrate-N concentrations in shallow groundwater, field tiles, and headwater streams draining from agricultural lands are often several times higher than those measured farther downstream where the loads were estimated. Fortunately, biochemical processes that occur in the upper reaches of streams act to remove nitrate-N, resulting in lower downstream concentrations. If these processes were not occurring, downstream nitrate-N loads would be considerably greater.

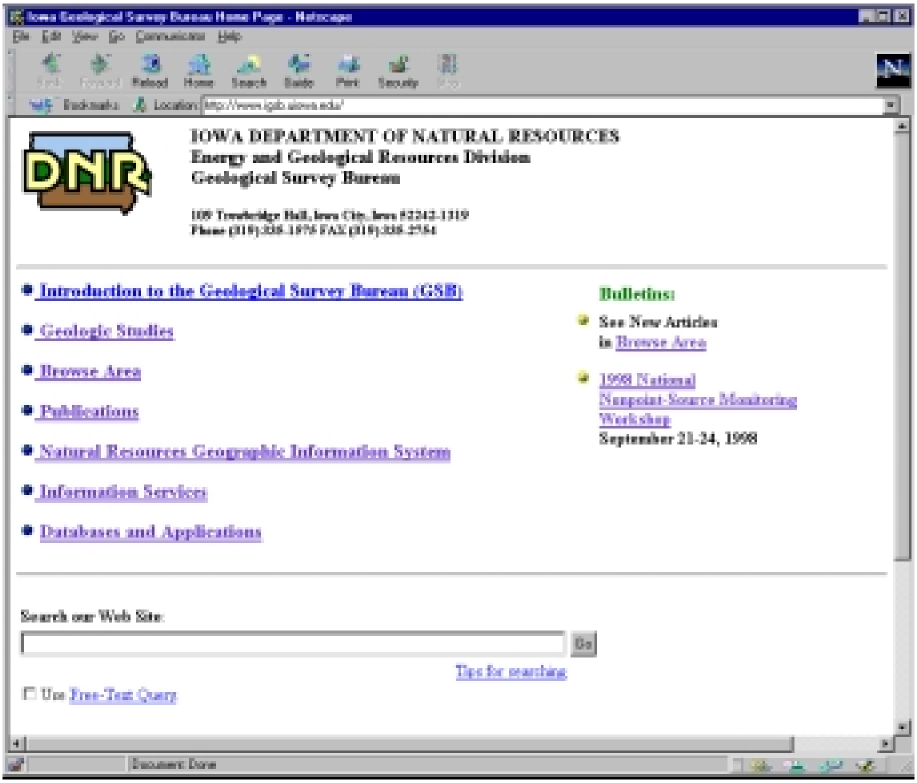
What can be done about Iowa's nitrate-N losses? Research, education and demonstration projects aimed at matching nitrogen inputs to crop needs, and therefore limiting excess nitrogen, were an important part of Iowa's 1987 Groundwater Protection Act, long before hypoxia became a household word. These efforts contributed significantly to a decade-long trend of lower N-inputs on Iowa's farms and fields, during which producers spent millions of dollars less on nitrogen fertilizers without sacrificing yields. Unfortunately, funding for these efforts has lagged, and nitrogen inputs appear to be inching upwards again. A refocus on nitrogen management seems in order. In addition, the natural processes that remove nitrate-N from streams have drawn the attention of researchers. Can in-stream nitrate removal be enhanced, through the use of constructed wetlands or other methods? Beyond agriculture, we need a better accounting of other nitrogen sources. Ultimately, it is in the best interests of Iowans, *and* our downstream neighbors, to improve the efficiency of nitrogen use, and to lower the nitrate concentrations in the state's surface water and groundwater.

LOG-ON TO IOWA'S GEOLOGY

JOOST A. KORPEL AND LYNETTE S. SEIGLEY

Do you have an interest in Iowa's geology? Are you a teacher looking for earth-science information for your class? Are you a researcher looking for detailed stratigraphic information on Iowa? Is that a geode you found in your back yard? Planning to visit Devonian Fossil Gorge and want to learn more about it? Information on these topics and others can be found on the Internet through the Geological Survey Bureau's (GSB) World Wide Web site at **www.igsb.uiowa.edu**.

The GSB web site (on-screen view, below) was introduced in March 1995 to make a wider array of geologic information directly available to all



IOWA DEPARTMENT OF NATURAL RESOURCES
Energy and Geological Resources Division
Geological Survey Bureau

109 Trowbridge Hall, Iowa City, Iowa 52242-1319
Phone (319) 335-1575 FAX (319) 335-2754

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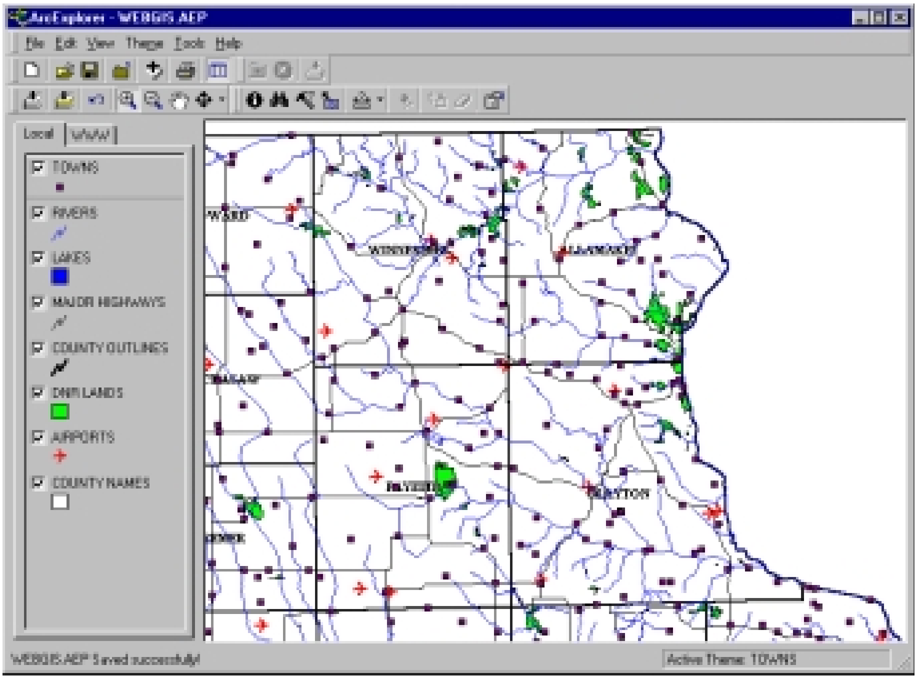

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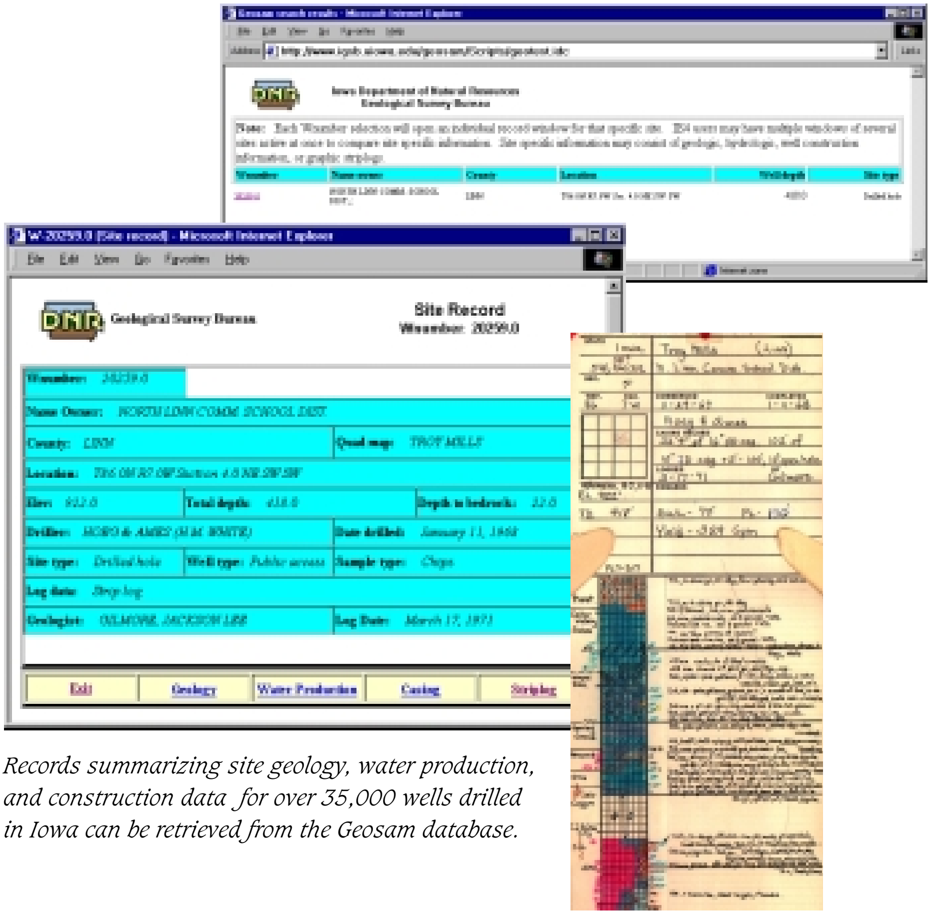
Active Theme: TOWNS

This map was created using ArcExplorer® and GIS coverages downloaded from the Geological Survey Bureau's NRGIS web page.

levels of potential users, from school children to consulting geologists. Visitors can find maps, photographs, general interest articles, technical abstracts, databases on geology and water wells, lists of available publications, geographic information system coverages, and information about GSB staff, programs, and services.

A popular section of our web site is the **Browse Area**, which contains well illustrated, general information about various aspects of the state's geology. Here, web users can find articles from past issues of *Iowa Geology* on topics including fossils, minerals, landscape features, state parks, Flood of 1993, meteorites, glacial history, and water resources. Maps include the 1998 bedrock geology map of Iowa, as well as state maps of landform regions and surface relief.

More advanced users will appreciate the **Natural Resources Geographic Information System (NRGIS) Library**. This remarkable "library" is a collection of more than 1,500 specialized geographic databases,



Site Record
Wnumber: 20259.0

Wnumber: 20259.0
Name Owner: NORTH LINN COMM SCHOOL DIST
County: LINN
Quad map: TROY MILLS
Location: T86 0N R7 0W Section 4.0 NE SW SW
Elev: 912.0
Total depth: 418.0
Depth to bedrock: 32.0
Driller: HOKO & AMES (H.M. WHITE)
Date drilled: January 11, 1968
Site type: Drilled hole
Well type: Public service
Sample type: Chips
Log data: Strip log
Geologist: GILMORE, JACKSON LEE
Log Date: March 17, 1971

Records summarizing site geology, water production, and construction data for over 35,000 wells drilled in Iowa can be retrieved from the Geosam database.

known as coverages or themes (such as rivers, lakes, counties, and state lands). Originally, the NRGIS Library was developed to improve access to and utility of natural resources data by DNR staff, to help make better decisions about the management, development, and protection of Iowa's natural resources. Now this extensive database is available to everyone via the Internet. The NRGIS Library web page is organized so that users can locate GIS data and associated documentation quickly and determine its applicability to their needs. All of the GIS coverages, including county boundaries, county roads, rivers, lakes, towns, and township/range/section lines, can be downloaded and viewed using a variety of commercially available GIS software. For users new to GIS techniques, there are links (under the “Help” prompt) to free software such as ArcExplorer® that can be used with our coverages to introduce you to using GIS information, as shown on p.9.

A new area of our web site is **Databases and Applications** for users with specific geologic data needs. Over the years, the GSB has developed many databases with valuable geologic information. Formerly accessed only through staff or by visiting our office in Iowa City, these databases are now available to anyone, anywhere, through the World Wide Web. Now linked are the Geologic Sample Database ("Geosam") and the Iowa UTM Coordinate Calculator.

Geosam is used to retrieve geologic, hydrologic, and well construction information on Iowa wells. The database can be searched by township, range, and section; owner name, county, topographic map name (7.5' series), or by a unique "W-number." Scanned well logs for all counties should be available by August 1999.

The Iowa UTM Coordinate Calculator is a technique that converts a legal land description (i.e., township, range, section, and quarter-sections) to a central point location expressed in Universal Transverse Mercator (UTM) coordinates, which are commonly used for Geographic Information System (GIS) mapping. Latitude and longitude are also calculated for the UTM point. This application only works for sites located in Iowa.

The **Geologic Studies** area of the web site highlights past and present investigations at the Geological Survey Bureau. Information is available under the categories of economic geology, environmental geology and hydrogeology, mapping, paleontology, stratigraphy, and structural geology. Examples of projects include the monitoring of groundwater quality around earthen manure-storage facilities, watershed studies of nonpoint-source pollution, the Cretaceous greenhouse world, the Manson Impact Structure, and the Midcontinent Rift in Iowa.

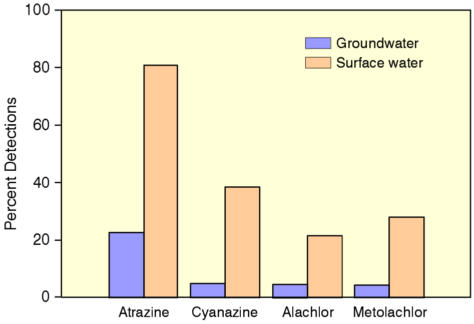
If you're not sure where to begin, try the search engine located on the first page of the web site. For example, type in "fossils" for a complete listing of articles on the web site that discuss fossils.

We encourage you to visit our web site at **www.igsb.uiowa.edu**. If you have comments, questions, or additional information you would like to find, please e-mail our **webmanager@igsb.uiowa.edu** or contact any of our staff listed in the directory (click on "Introduction to the Geological Survey Bureau – Organization and Staff").

Log-on and happy surfing!

PESTICIDE TRENDS
IN IOWA'S SURFACE AND GROUNDWATER, 1980 – 1995

MARY P. SKOPEC



Frequencies of detection for four commonly used herbicides in Iowa.

The 1987 Groundwater Protection Strategy identified pesticide contamination of groundwater as one of the most important issues to Iowans. More than ten years later, this issue remains a primary concern. Since 1991, the U.S. Environmental Protection Agency (EPA) has directed states to take primary responsibility in developing pesticide management plans (PMP) to deal with agricultural chemicals. Because of variations in geology, soil, and landscape features among the states, the PMP strategy allows states to implement a pesticide-specific plan to best protect their water resources. Part of the PMP process includes an inventory and assessment of the current water-quality problems within the state. As a result, the Iowa Department of Natural Resources, Geological Survey Bureau (GSB) in cooperation with the Iowa Department of Agriculture and Land Stewardship (IDALS) has developed a database of pesticide analyses to track the occurrence of agricultural chemicals in Iowa's groundwater and surface waters. This database, the Iowa Pesticide Water Resources Database (IAPEST), is a compilation of all the data from water-quality monitoring and research projects conducted in the state during the last 30 years. As such, it is a large, heterogeneous database including thousands of sites covering more than 75 pesticide compounds.

To provide information for the PMP process, the GSB began to evaluate IAPEST to identify trends in the occurrence of pesticides in Iowa's waters. Four commonly used corn herbicides, atrazine (Aatrex*), alachlor (Lasso), cyanazine (Bladex) and metolachlor (Dual), were analyzed for changes in detection rate through time. These chemicals were the four most commonly detected pesticides in Iowa's waters during the period 1982-1995. The

ESTIMATED ANNUAL HERBICIDE USE IN IOWA: 1979–1996

	Acetochlor (Harness) 1,000 lbs a.i.	**rank***	Alachlor (Lasso) 1,000 lbs a.i.	**rank**	Atrazine (Aatrex) 1,000 lbs a.i.	**rank**	Cyanazine (Bladex) 1,000 lbs a.i.	**rank**	Metolachlor (Dual) 1,000 lbs a.i.	**rank**
1979	NR	--	15,581	**1**	6,642	**4**	8,513	**3**	1,674	**7**
1985	NR	--	12,019	**1**	9,716	**4**	10,366	**3**	11,815	**2**
1990	NR	--	7,802	**2**	7,548	**3**	5,120	**5**	9,981	**1**
1991	NR	--	8,689	**2**	7,354	**3**	6,583	**4**	11,839	**1**
1992	NR	--	9,223	**2**	8,160	**3**	6,943	**4**	12,204	**1**
1993	ID	--	6,223	**4**	6,659	**3**	7,947	**2**	10,288	**1**
1994	2,164	**6**	4,507	**4**	7,471	**3**	7,768	**2**	10,664	**1**
1995	6,205	**3**	766	**12**	6,490	**2**	5,296	**4**	8,374	**1**
1996	7,584	**3**	728	**12**	7,907	**2**	4,905	**4**	10,148	**1**

Based on *Pest Management in Iowa: Planning for the Future*, 1996, by Diane Mayerfeld, George Hallberg, Gerald Miller, Wendy Wintersteen, Robert Hartzler, Susan Brown, Michael Duffy, and Jerald DeWitt, Iowa State University publication IFM 17, University Extension, Iowa State University, Ames, IA, 89 pp.

* rank of use within the state of Iowa

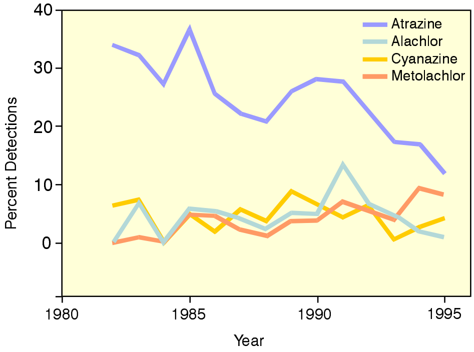
NR = not registered for use

ID = insufficient data

a.i. = active ingredient

graph on page 12 shows the frequencies of detection for these four products in Iowa's surface and groundwater. Atrazine was found in 23% of all groundwater samples followed by alachlor (5%), cyanazine (5%), and metolachlor (4%). In surface water samples collected from 1980-1995, the detection rates were: atrazine (81%), alachlor (21%), cyanazine (38%), and metolachlor (28%).

While these numbers present an overall picture of the occurrence of herbicides in Iowa's waters, they do not illustrate how this contamination has changed through time. The table above lists the pounds of pesticide active ingredient (lbs. a.i.) used and the ranking of use (based on pounds) in the state from 1979 through 1996. This table illustrates the continually evolving nature of agriculture as new herbicides enter into the marketplace and replace older products. Such was the case with the herbicides alachlor (Lasso) and acetochlor (Harness). In 1979, alachlor was the most heavily used pesticide in Iowa with more than 15,000,000 lbs. a.i. applied to the state's crops. This trend continued through the 1980s, but starting in the

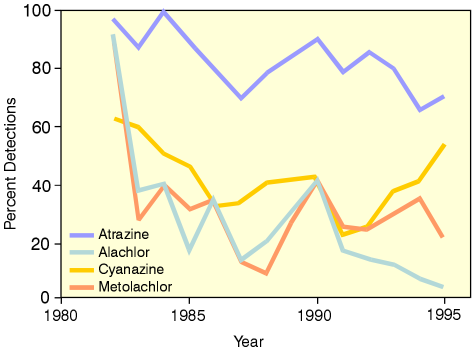


Frequencies of detection for common herbicides in Iowa groundwater.

early 1990s, alachlor use plummeted as it was rapidly replaced by new herbicides such as acetochlor that entered the market in 1994. Total alachlor use was 728,000 pounds of active ingredient in 1996, roughly 6% of the amount used in 1985. This drop in alachlor use is reflected in the declining frequency of detection (see graphs above). The highest frequency of detection of alachlor in groundwater was 13% in 1991. Since then, this frequency has steadily dropped and in 1995 was less than 1%. For surface water, the rate of alachlor detection peaked in 1990 at just over 40%, but by 1995 was only 3%.

While trends in alachlor detection can be attributed to changes in consumer preference and economic forces that resulted in a drop in alachlor use, the story for atrazine is a bit different. Atrazine use has not changed much since 1979; its annual use has ranged from just over 6,000,000 lbs. a.i. to almost 10,000,000 lbs. active ingredient. During this time, atrazine has remained one of the top-five most used pesticides. Despite this, it appears that atrazine detection rates are decreasing (see graphs). In groundwater, atrazine detection rates have steadily decreased over the last five years from 28% in 1990 to 12% in 1995. Atrazine detection rates in surface water have dropped by 20% in the last five years. This trend appears to be the result of management factors. State and federal regulations have placed restrictions on atrazine applications including a reduction in the maximum rate of use, elimination of fall applications, and prohibited use near agricultural drainage wells, tile intakes, sinkholes, and lakes. As a result, lower amounts of atrazine are incorporated into herbicide tank mixes with other products. This practice has led to atrazine being applied to more acres, but at lower rates. Therefore even though the total pounds of atrazine have not decreased, the lower application rates appear to be having a positive impact on water quality.

Metolachlor has been the most used pesticide in Iowa (based on total pounds) since 1990. Its annual use has been fairly stable for the past decade



Frequencies of detection for common herbicides in Iowa surface water.

and is in the 8,000,000 to 12,000,000 lbs. a.i. range. Not surprisingly, statewide trends of the rate of metolachlor detection do not show any significant changes.

The trends in cyanazine detection are a bit perplexing. Cyanazine use peaked in 1985 at more than 10,000,000 lbs. of active ingredient. But by 1990, cyanazine use was half of the 1985 value. Use steadily increased from 1990 to 1993, but began to decline again after hitting a maximum use rate of 7,900,000 lbs. a.i. in 1993. Cyanazine use in 1996 was an all-time low of 4,900,000 lbs. active ingredient. This declining use is most likely the result of a manufacturer's planned phase-out of this chemical. The cyanazine detection trends do not neatly fit the use patterns, however. While the early 1990s did show a decrease in detection rates for both surface and groundwater, the detection rates have steadily increased since 1993. The reason for this trend is not known at this time and requires further exploration.

Overall, the trends of pesticide detections in Iowa seem to be encouraging. However, it is important to note that these trends are intertwined with management decisions, marketing strategies, consumer preferences, and regional use patterns. As pesticide use patterns and management decisions evolve, so may the pesticide trends within Iowa's waters.

The decreases in atrazine and alachlor concentrations in Iowa's surface and groundwater should be seen as considerable progress toward the goals of the 1987 Groundwater Protection Act. However, much room for improvement remains. The ever-changing face of contemporary agriculture requires that we continue to monitor and protect our precious water resources.

** Use of brand names is for reference purposes only and does not constitute an endorsement by the Iowa Department of Natural Resources or the Iowa Department of Agriculture and Land Stewardship.*

IAPEST has been supported in part by IDALS, Laboratory Division, Pesticide Bureau, through grants from the U.S. EPA, Region 7 Water, Wetlands, & Pesticides Division.

PILOT KNOB STATE PARK

DEBORAH J. QUADE

One of north-central Iowa's most prominent natural landmarks is easily seen along Hwy. 9 across southern Winnebago County. Pilot Knob, an isolated cone-shaped hill, rises 250 feet above the surrounding terrain and provides a commanding view of the Iowa countryside. For early settlers, the mounds and knobby hills of this region served as "pilots" for those navigating the expansive unmarked prairie, and the most prominent of these became known as Pilot Knob. The conical hills, irregular ridges, and interlaced wetland swales all reflect the area's recent contact with glaciers.

Pilot Knob State Park lies along the eastern margin of a former ice sheet that surged into Iowa about 15,000 years ago and reached its most southern extent, at the present location of Des Moines, about 14,000 years ago. This ice sheet and the deposits it left behind are referred to as the Des Moines Lobe. After the initial glacial surge, the ice became stagnant across the north-central Iowa landscape. This was followed by several less extensive re-advances over the next 1,500 years. Along the lateral margins of the Lobe, stagnant ice from the older Altamont advance was overridden by younger, re-advancing Algona ice (see map, p.18). This action created broad areas of high-relief hummocky topography, better known as "knob and kettle terrain," which is characteristic of the park and vicinity (see photo, p.19).

Deb Quade

The observation tower, built of glacial boulders, invites visitors to view Iowa's landscape from the top of a glacial kame.

The landscape we see today is a topographic reversal of the former ice-covered landscape. Today's knobby hills represent former cavities and crevices within the ice. Glacial meltwater was funneled into these holes in the disintegrating glacier, filling the openings with sand and gravel. Subsequent melting of the ice left hills or knobs of sand and gravel known as kames. Kames are classic ice-contact glacial landforms, and they typify the Pilot Knob State Park region. Kettles, closely associated with kames, are bowl-shaped depressions that also illustrate the reverse of ice-covered terrain. Kettles formed when large, buried blocks of ice melted from the landscape.

The nearby Winnebago River (photo, p.19, lower left) was a drainage outlet during melting of the Algona ice advance. The outwash deposits of sand and gravel along the river are referred to as "valley-train" deposits because they were left by meltwater flowing in a long, narrow route away from the edge of the glacier.

Another landform feature associated with melting of the Des Moines Lobe glacier is Deadman's Lake. Actually, recent studies have identified

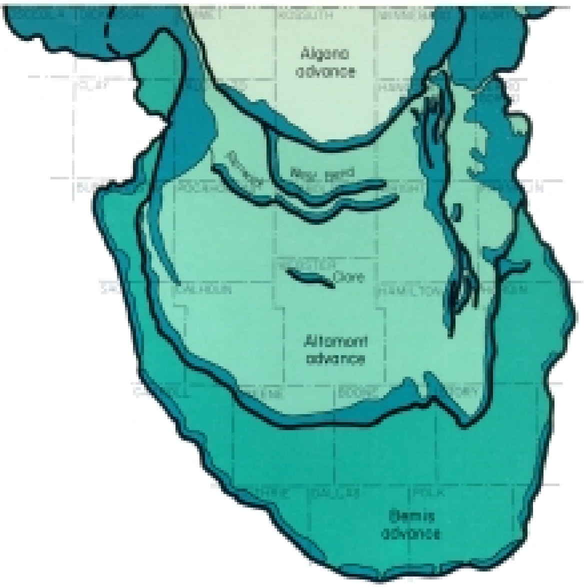
Lynette Seigley

Dick Baker

Diana Horton

*Deadman's Lake (**top**), a peatland nestled among sandy knobs, is fed by groundwater and rainfall. It hosts a floating mat of unusual vegetation including* Sphagnum *moss (**middle,** brownish plants) and the beautiful sundew (**bottom**).*

Glacial Advances of the Des Moines Lobe



EXPLANATION

〰 Limits of glacial advances

▨ Areas of prominent ridges and knob-and-kettle terrain

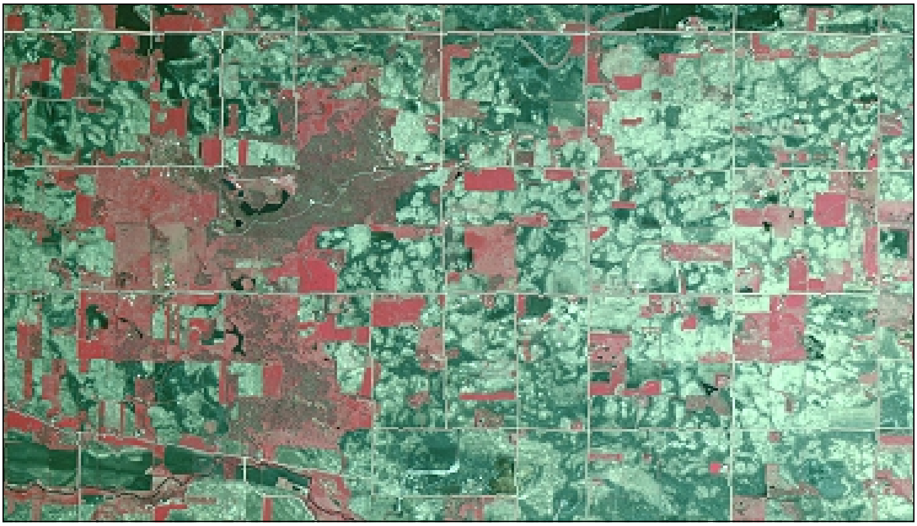
▨ Areas of generally low-relief glacial terrain

0 10 20 30 mi.

0 10 20 30 km.

this feature as a fen, a relatively rare type of peatland that is fed by groundwater as well as rainwater. The 25-acre wetland is nestled among sandy knobs within the park. Most likely, the basin formed during melting of the Algona and Altamont ice advances. Deadman's Lake is unique in that its western portion has a 3-acre floating mat of vegetation dominated by *Sphagnum* moss. At one time this mat covered most of the lake, however harvesting during the late 1920s greatly reduced its size. Other unusual plants associated with the floating mat include a rare species of sedge (*Carex cephalantha*) and the sundew (*Drosera rotundafolia,* photo, p.17), which are not found elsewhere in the state.

Since the last glacial episode, many changes have occurred in the vegetation assemblages at Pilot Knob. Studies of fossil pollen grains in soil cores collected from Deadman's Lake indicate that vegetation around the lake changed from oak savanna to prairie about 8,000 years ago. By 3,000 years ago, the prairie was replaced by oak forest. Evidence of the more recent European settlement became apparent with the appearance of certain "weeds," primarily *Ambrosia* (ragweed). Reports from early visitors indicated that the Pilot Knob area was at least partially wooded. Forest and prairie apparently co-existed in the knob and kettle terrain



Numerous sandy knobs (light) and wetter depressions (dark) of the Altamont moraine are present in the Pilot Knob vicinity. The forested park (upper left half) and its lakes (black) lie south of Hwy. 9, which closely follows the top edge of this color-infrared image.

throughout Hancock, Winnebago and Worth counties, primarily because the oak-covered knobs were protected from fire by intervening wet depressions.

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. In 1934, Civilian Conservation Corp workers began building and landscaping projects at the park. Within four months they had constructed roads, trails, a rock shelter, an outdoor amphitheater, and the thirty-five-foot observation tower (photo, p.16). Glacial erratics (boulders transported by the ice) were collected from nearby fields for construction of the buildings and tower. These erratics consist mostly of igneous and metamorphic rocks that originated in Minnesota and Canada. In 1968, the entire park (365 acres) received State Preserve status, and in 1978 an additional 160 acres was acquired for parkland.

Pilot Knob State Park still serves as a modern-day landmark for travelers crossing the former expanse of north-central Iowa prairie. The gravel hummocks and sparse stands of burr oak reflect Iowa's past glacial and vegetation history, and create the scenic beauty for which Iowa's knob and kettle country is known.

PROTECTING THE SOURCE
OF YOUR DRINKING WATER

KEITH SCHILLING
AND MARY HOWES

Have you ever wondered where the water you drink comes from? In Iowa, chances are if you traced the water back through its distribution system, you would find a well pumping water out of the ground. But where does this groundwater come from? The question is important to public water suppliers who are entrusted with delivering good quality water to your home. Water utilities that can identify the source of their water can work to protect these areas from contamination and prevent potential contaminants that are spilled on the ground or released below ground from reaching their wells. As part of a new Department of Natural Resources effort called the "Source Water Protection Program," the Geological Survey Bureau will be helping public drinking water suppliers over the next four years to determine protection areas for their water supply sources. States such as Iowa that receive Federal funds for water-supply improvement projects are mandated by the 1996 Federal Safe Drinking Water Act Amendments to conduct this source water delineation and assessment program.

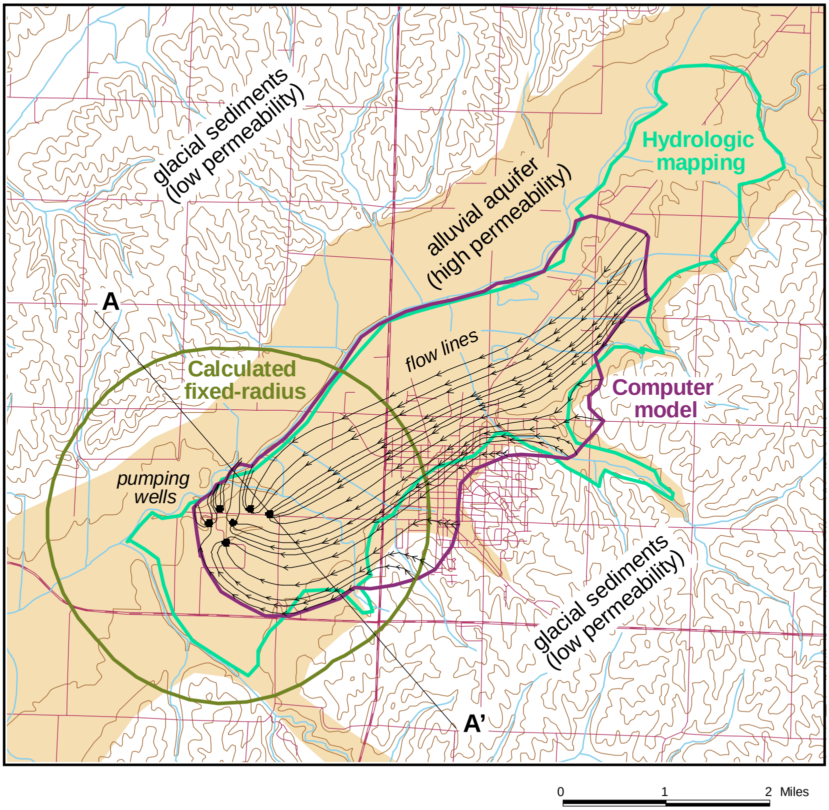
The geological sources of groundwater are known as aquifers, and they vary greatly across the state in terms of their depth, horizontal extent, composition, and permeability. How are protection areas for wells pumping from these diverse sources determined? It often depends on the amount of existing information about the wells and the aquifers they tap. In the case where no information is available, it is easiest to select an arbitrary area, such as a 2,500-ft radius circle around a well. This arbitrary fixed-radius method then assumes that all water within 2,500 feet of a well constitutes its protected source. When information is available, a more accurate method for defining a protection area involves the concept of "time-of-travel " (TOT), or how far water travels in an aquifer during a specified period. For example, if water requires ten years to travel 2,600 feet, then a source water protection area, based on a 10-year TOT, would extend 2,600 feet from the well. For Iowa's Source Water Protection Program, a two-year time-of-travel distance is the minimum recommended, but a ten-year distance is strongly encouraged. Ideally, a TOT should be selected that would allow adequate time for a water utility to respond to a contaminant release by cleaning up the source area or by replacing the water supply.

Time-of-travel, then, is the criterion the Geological Survey Bureau will use whenever possible to identify the area around a well that will become the focus of protection efforts. The most commonly used methods to delineate the geographic extent of this area include: 1) the calculated fixed-radius method; 2) hydrologic mapping; and 3) computer modeling. The value of each method depends on the quantity and quality of information available about the individual wells, the aquifer involved, and the hydrogeologic setting of the area.

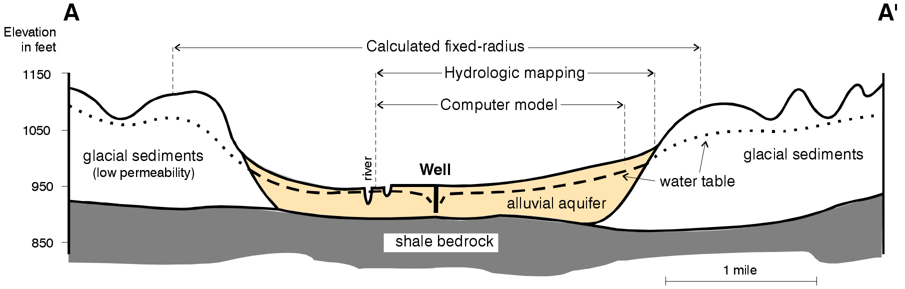
The accompanying illustration compares the results of each TOT method to determine a source water protection area for six wells installed in a shallow alluvial aquifer. A cross section through the valley (see line A – A' on map, p.22) shows a three-dimensional view of this aquifer. Alluvial aquifers occupy river valleys and are typically composed of layers of sand and gravel deposited by flowing water. These aquifers are attractive to water suppliers because the shallow, highly permeable sand and gravel provides abundant groundwater that is relatively free of natural contaminants (e.g., hardness, iron). However, alluvial aquifers often lack thick overlying layers of low permeability materials to slow the recharge from above, and thus they are particularly vulnerable to contaminants introduced at the land surface.

The least complicated method for determining a source water protection area is a calculated fixed-radius, consisting of a circle drawn around a well to delineate a specified time-of-travel. The radius of the circle is defined by the well's pumping rate, the thickness and permeability of the aquifer, and the specified time-of-travel. For multiple wells, the calculated circles are merged to define the protection area for the entire wellfield. This method is relatively easy to perform with limited information, but it often results in a larger wellhead management area than other methods. In a narrow alluvial valley for example, this technique may unnecessarily include the surrounding uplands in the protection area.

A second method uses the physical and hydrologic characteristics of the area to map the protection zone. With this method, the protection area around a well is governed by the presence of groundwater flow boundaries which are based on rock and soil characteristics, the extent and thickness of the aquifer, and surface and groundwater drainage divides. In the example, boundaries are established to the east by lateral extent of the alluvium and low permeability of the valley walls,



Protecting a water supply requires delineation of a time-of-travel of groundwater flow. Three methods are compared here for a community well field.



A cross section of the alluvial aquifer shows hydrogeologic conditions that affect groundwater movement and the cross-valley extent of each delineation method.

and on the west by a river that acts as a constant recharge boundary (constant supply of water). Because groundwater flow within alluvial aquifers usually parallels the direction of river flow, in this case northeast to southwest, the delineated protection area is primarily along the river. One difficulty in using this method is the accurate determination of the upstream and downstream boundaries that correspond to the selected TOT distance.

A third method of delineating a protection area relies on a computer program to model the groundwater flow system. Computer models typically require large inputs of data describing the dimensions and hydrogeologic properties of the aquifer materials in order to simulate the aquifer's behavior. Information is also needed about well construction, pumping rates, river conductance (how much water flows through the base of the river channel), recharge and evapotranspiration rates. Models can be either two- or three-dimensional representations of groundwater systems. In our example, a three-dimensional model was used to simulate groundwater flow in response to pumping from six production wells. Water flow paths are determined in the model by placing "particles" at the wells and instructing the computer to trace their routes backward for the specified TOT, here ten years. The area bounded by the flow paths then becomes the source water protection area. The results show that little groundwater is drawn from the down-gradient side of the pumping wells (southwest) and that the protection area extends a considerable distance up-gradient to the northeast. Although the results of modeling often imply a high level of accuracy, one of the fundamental principles of groundwater modeling is that without sufficient data to properly formulate a model, the results may be no closer to reality than the arbitrary fixed-radius method.

The methods used to delineate source water protection areas each require increased data to provide reliable estimates of protection areas. The Geological Survey Bureau will select a delineation method for each public water supply based on the quality and quantity of hydrologic data that is available. Over the next four years, protection areas will be determined for approximately 1,950 public water supplies consisting of approximately 5,300 wells. For many public supplies, the arbitrary fixed-radius method will be sufficient. Much greater accuracy will be required for more vulnerable areas. Though a daunting task, identifying and protecting these areas will ensure that high quality water will be available for generations to come.

FORT DODGE GYPSUM
A SALT FROM IOWA'S JURASSIC SEA

RAYMOND R. ANDERSON

One of Iowa's most valuable mineral resources is found in a small area of central Webster County, in and around the town of Fort Dodge. The resource is gypsum, and this deposit, part of the Jurassic-age Fort Dodge Formation (about 145 million years old), comprises one of the most pure gypsum deposits known on Earth. The occurrence of this gypsum was first reported in the 1850s from natural exposures at the land surface, and it was mined as building stone by early settlers in the area. Today, gypsum is used primarily to produce wallboard (also called Sheetrock), which is valued for its versatility, fire-retarding properties, and ease of installation. The value of gypsum mined annually in the Fort Dodge area to feed this flourishing gypsum wallboard industry is about $10 million.

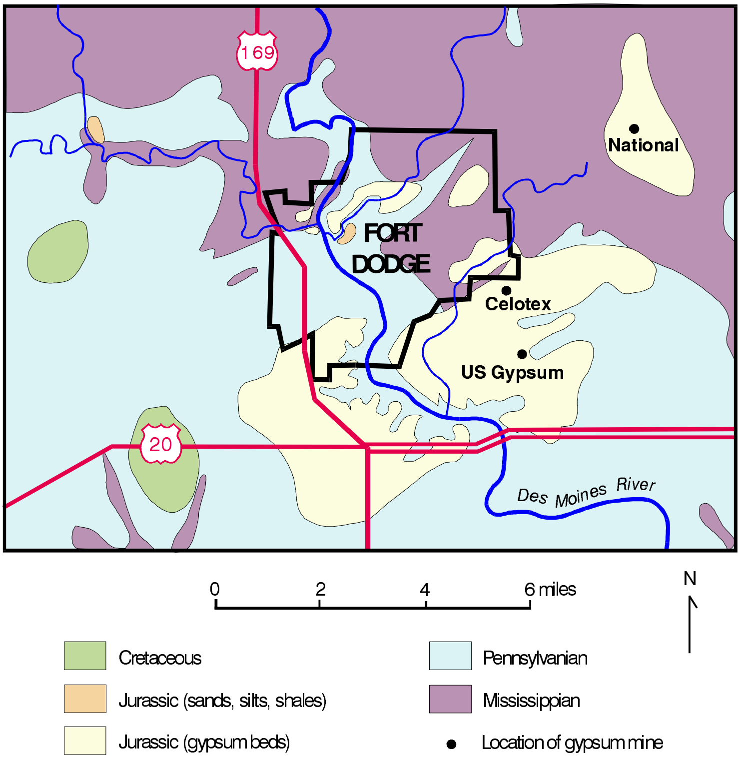
Gypsum is a soft, white to gray, "chalky" mineral (see photo, p.25) composed of calcium sulfate and water ($CaSO_4 \cdot 2H_2O$). The gypsum at Fort Dodge, like most commercial-scale deposits, had its origins in the evaporation of seawater from a restricted shallow basin. Water from the Jurassic-age Sundance Sea passed over a low-lying barrier into the basin, where the mineral salts became concentrated by evaporation in the hot semi-tropical sun. When the brine became sufficiently concentrated, gypsum crystals formed and settled to the floor of the basin. The gypsum beds at Fort Dodge average over 95% pure gypsum and contain no anhydrite (a common alteration mineral contaminant.) The extent of the original depositional basin is unknown, but it was certainly larger than the 15 square miles of gypsum remaining today.

As the Jurassic passed into the Cretaceous Epoch about 135 million years ago, the continent slowly drifted northward out of the dry latitudes where the gypsum formed, into wetter, more temperate latitudes closer to North America's present position. Great Cretaceous rivers flowed across Iowa, first eroding most of the original gypsum deposit, then reburying the region with river sediments. The remaining gypsum was buried for tens of millions of years until a new episode of erosion uncovered it, and again began to wear away the resource. Most recently, the gypsum bed was buried once again, this time by glacial materials carried by continental ice

Thin light and dark bands seen in this 30-inch high ledge of Fort Dodge gypsum may reflect seasonal variations in the evaporation and crystallization of the gypsum salt about 145 million years ago.

sheets that advanced into Iowa beginning about 2.5 million years ago.

In 1852, geologist David Dale Owen first reported the occurrence of gypsum in the area that is now Fort Dodge. In the first geological survey of the region, he reported a "supply {of gypsum that} may be considered as almost inexhaustible," exposed along the Des Moines River. In 1893, Iowa Geological Survey geologist C.R. Keyes described the gypsum deposit at Fort Dodge as "by far the most important bed of plaster-stone known west of the Appalachian chain if not in the United States." The success of the first gypsum mill in the region, the Fort Dodge Plaster Mill built in 1872, led to the construction of others. By 1902, seven mills were operating and producing a variety of products including building blocks, mortar, plaster, roofing and floor materials. During the 125 years of industry operations in Iowa, at least 30 different business entities have mined or processed Fort Dodge gypsum. Today three companies operate mines, running two shifts a day, and four


Geology of the Fort Dodge Area

companies process gypsum, operating their mills 24 hours a day. The most recent production data available (1994) indicates that a total of about 1.5 million tons of Fort Dodge gypsum are mined yearly, with a value of $10 million. The Fort Dodge area accounts for about 75% of Iowa's total gypsum production, and the state, as a whole, is second only to Oklahoma in total production. Fort Dodge gypsum constitutes about 12–13% of the total U.S. production. Because of the limited extent of the gypsum resource at Fort Dodge, Owen's "inexhaustible" supply will be depleted within about 30 years at its current mining rate.

Although it was mined from

underground in the past, gypsum is currently extracted by stripping in open pits (see cover photograph). After mining, the gypsum is processed into a variety of products, the most common of which are wallboard and plaster-of-Paris. To produce wallboard, the gypsum is "calcined," an industrial term for the process that includes the grinding of gypsum to a fine powder which is then heated for 2 to 3 hours. During the heating process, the powdered gypsum goes through a complex series of temperatures (as high as 204°C) that drives off some of the water to produce a material called ß-hemihydrate. To manufacture the wallboard, the ß-hemihydrate is combined with water to form a slurry that is poured onto a continuous strip of special paper. As the slurry crystallizes, forming tiny interlocking needles of gypsum, a top layer of paper is added with rollers that insure the proper thickness. The wallboard then goes through heaters that expel excess water as the board solidifies. It is then cut to size and stacked for shipping.

Gypsum from the Fort Dodge area was used to create one of the great hoaxes in U.S. history. In the 1860s, New England native George Hull traveled to Fort Dodge and purchased one acre of land along Gypsum Creek. He engaged local quarrymen to excavate the largest block of gypsum possible (about 2 feet thick, 4 feet wide, and 12 feet long). The block was shipped to Chicago where sculptors carved it into the form of a giant man. Then they scoured the sculpture with a sandy sponge to remove the chisel marks and "aged" the figure by pitting it with needle-tipped hammers and discoloring it with sulfuric acid. The sculpture, now appearing very old, was shipped to New York and secretly buried on an up-state farm near Cardiff. A year later, while digging a well, the "petrified man" was "discovered" and proclaimed the "eighth wonder of the world." Despite being quickly identified as a hoax by eminent Yale paleontologist O.C. Marsh, the Cardiff Giant went on tour, earning Hull about $20,000. The giant came home to Fort Dodge for display between 1913 and 1923, and then was returned to New York where it is currently on exhibit at the Farmers Museum in Cooperstown.

For further information:

R.D. Cody, R.R. Anderson, and R.M. McKay, 1996, Geology of the Fort Dodge Formation (Upper Jurassic) Webster County, Iowa: Iowa Department of Natural Resources Geological Survey Bureau Guidebook No. 19, 74 pages.

Rodenborn, L.V., 1972, A History of the Gypsum Industry in Fort Dodge and Webster County, Iowa: privately printed, 127 pages.

New Books on Iowa's Geology

Iowa's Minerals

Their Occurrence, Origins, Industries, and Lore

by **Paul Garvin**

A comprehensive and informative new book about minerals in Iowa was recently published by the University of Iowa Press. *Iowa's Minerals – Their Occurrence, Origins, Industries, and Lore* was written by Dr. Paul Garvin, Professor of Geology at Cornell College in Mount Vernon. The book includes origins of Iowa minerals, tips on collecting, major mineral occurrences, a history of the state's mineral industries, and entertaining stories about Iowa's minerals. Illustrations, including rich color plates, and appendices help readers identify minerals as well as locate exhibits and mineral collecting organizations throughout Iowa. *Iowa's Minerals* will benefit scholars, collectors, and the general public as it improves understanding of these basic building blocks of Iowa's earth materials. *Garvin, Paul, 1998, Iowa's minerals – their occurrence, origins, industries, and lore. University of Iowa Press, Iowa City, 260 p. Price: $19.95 paperback; $39.95 hardcover.*

Iowa's Geological Past

Three Billion Years of Change

by **Wayne I. Anderson**

An authoritative summary of Iowa's geologic record, written by Dr. Wayne Anderson, Professor of Geology at the University of Northern Iowa, is scheduled for release this December by the University of Iowa Press. *Iowa's Geological Past – Three Billion Years of Change* is not just a revision of his earlier book, *Geology of Iowa*, but is a fascinating new look at Iowa's varied geological history, incorporating recent discoveries and current interpretations. Anderson's account and its abundant illustrations will appeal to a broad audience as it examines Precambrian mountains and volcanoes, the Paleozoic's tropical inland seas and coral reefs, roaming dinosaurs and a giant meteor impact in the Mesozoic, and the mammoths and mastodons of the Cenozoic's Great Ice Age. *Anderson, Wayne I., 1998, Iowa's Geological Past – Three Billion Years of Change: University of Iowa Press, Iowa City, 440 p. Price: $24.95 paperback; $49.95 hardcover.*