number 9

Iowa Geology

1984

Iowa Geology 1984

IOWA GEOLOGICAL SURVEY
123 North Capitol Street
Iowa City, Iowa 52242
319-338-1173

Donald L. Koch
State Geologist and Director

Cover Illustration:

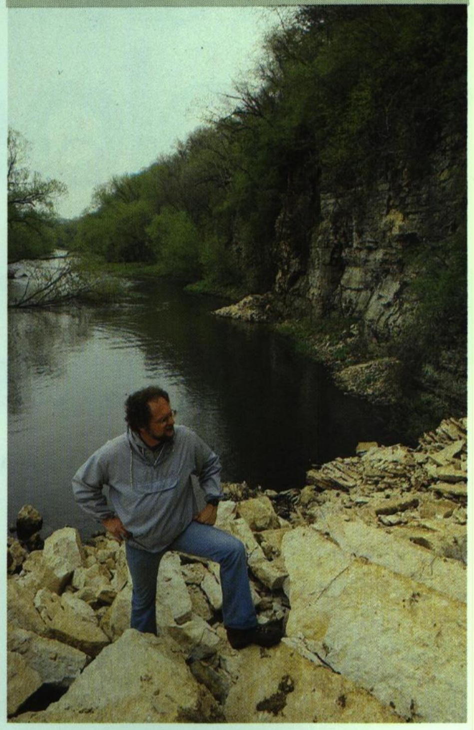
The cover is designed to show a scene characteristic of the lead-mining activity at the New Era Mine which was in operation near Dubuque about 1908.

Cover illustration by Patricia Lohmann.

Jean C. Prior .... Editor
Patricia J. Lohmann .... Publication Designer, Artist

Editor's Note: I would like to acknowledge the helpful assistance of Pat Lohmann, Bernie Hoyer, Mary Pat Heitman, and Sheila Baker as well as the timely cooperation of the individual authors.

TABLE OF CONTENTS



THE DIRECTOR'S VIEWPOINT

Geology is no longer a subject with a low profile — it has too much to do with how people live. Information about earth materials beneath the land and the natural processes at work above and below the ground, as seen within the framework of geologic time, is vital to those charged with protecting our state's land and water resources. To provide the best information to decision-makers requires continued research efforts; to effect an increased public awareness requires communication of the results. *Iowa Geology* is one means of communicating with Iowans about significant aspects of the state's geology and hydrology. Our goal is to acquaint readers with some of the research, service, and advisory functions performed by Survey staff, and to bring further understanding to the role that geologic and hydrologic investigations play in the intelligent management of our state's natural resources.

Few Survey programs are launched without any background information. A considerable amount of data has been accumulated through the efforts of many Survey staff, over many decades. It may be in the form of raw field notes, logs of wells, published reports, or computer-formatted data; each bit of information has numerous applications, and is used repeatedly.

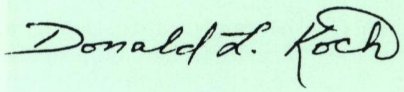
One of these important sources, or "tools of the trade," basic to almost every facet of our activities, is topographic maps. They are an indispensable aid to office-related as well as nearly every field-related project. These maps provide valuable, detailed information on landforms and elevations, water and woodland areas, and man-made or cultural features. They also provide precise geographic coordinates for locating and referencing specific features or sites. The ability to accurately plot well locations and determine their elevations is important for piecing together the three-dimensional picture of the unseen sequence of rock and water resources that occur beneath Iowa's landscape. For example, the depth to rock or groundwater encountered in wells is subtracted from the elevation of the land surface, enabling geologists to contour the topographic characteristics of the buried bedrock surface or the configuration of the standing-water level in a regional bedrock aquifer.

Topographic maps are made for each state by the U.S. Geological Survey, a branch of the Department of the Interior. They have been making these maps since 1882. The once arduous and time-consuming field process is now replaced by aerial photography and sophisticated stereoscopic plotting instruments. As in other states, the topographic mapping program in Iowa has had a long history. This effort began in 1907, but the program was interrupted from 1931 to 1950 and again from 1971 to 1975. Our objective has been to attain complete map coverage of the state's 56,290 square miles.

Of the several kinds of topographic maps of Iowa being prepared (and described in this issue), the 7.5 Minute Series is the focus of the current effort to acquire complete coverage of the state. The 7.5 minute mapping program began in 1950, but progress was slow. By 1975, Iowa ranked near the bottom of the national list in map coverage, with only about 60 percent of the mapping completed. An accelerated program was needed to provide scientists, planners, engineers, industry, and the public with the maps they required. The remaining quadrangles were prioritized through a State Mapping Advisory Committee, and the state's annual funding support was quadrupled. Currently, only two percent of the mapping remains to be completed. By the end of this year Iowa will join the sixteen other states that now have 100 percent coverage.

Iowa has invested nearly a million dollars in this cooperative program, an amount matched by the federal government. The investment pays dividends in cost savings for planning highways, pipelines, power transmission lines, airports, industrial plants, and other types of construction. The maps also facilitate the development of flood control, soil conservation, and reforestation projects. The rapidly growing list of users now includes many who have discovered the advantages of topographic maps in the pursuit of outdoor activities such as hunting, fishing, canoeing, hiking, cross-country skiing, bicycling, and vacationing.

The utility of topographic maps to our assessment of the state's water, soils, and mineral resources is invaluable. The availability of these maps through the Iowa Geological Survey office is part of our service to the public. These maps add substantially to the information base which permits Survey staff and others to ably address questions and issues about developing, managing, and protecting Iowa's natural resources.

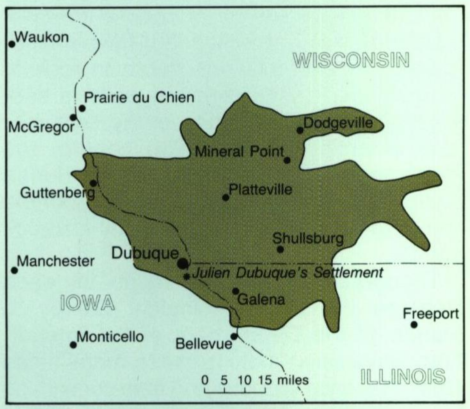


Donald L. Koch
State Geologist and Director

LEAD AND ZINC MINING IN THE DUBUQUE AREA

Greg A. Ludvigson and James A. Dockal

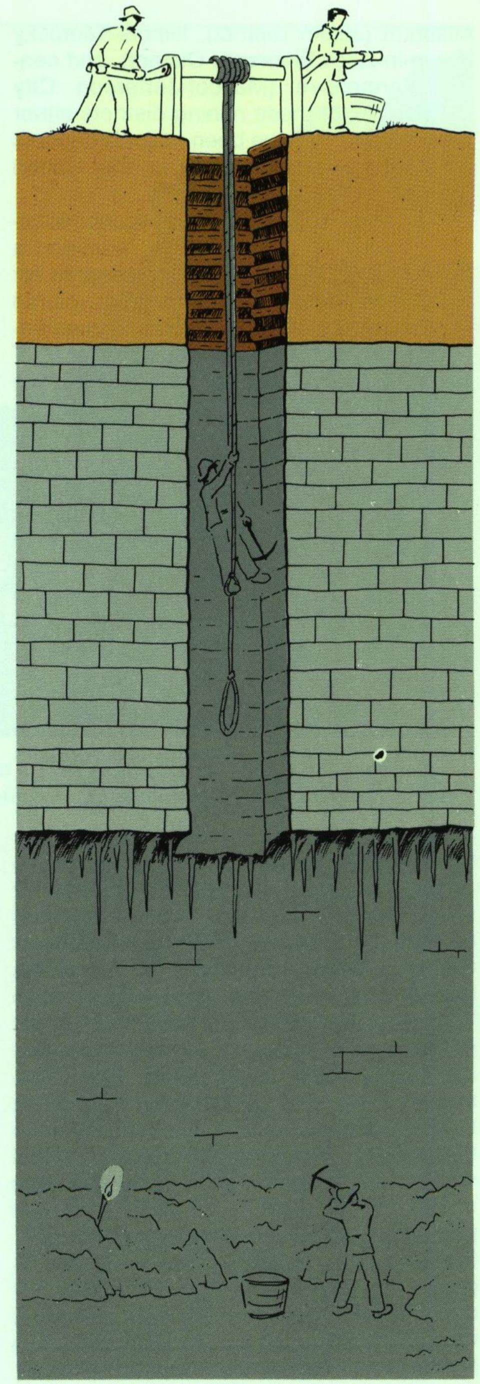
Historical Significance: While traversing Iowa's rich agricultural landscapes, modern travelers see little to remind them that the state's earliest European explorers were attracted here by metallic mineral wealth. The first written accounts by French travelers in the Upper Mississippi Valley indicate that Indian fur trappers working with French *voyageurs* were engaged in primitive lead mining and smelting activities in this region before the year 1650. By 1682 the lead deposits of the Upper Mississippi Valley were known in Europe through the writing of Nicholas Perrot, and by the end of the century, French and English maps of North America clearly showed lead mines at the present sites of Dubuque, Iowa and Galena, Illinois. By 1788, a charismatic and energetic French-Canadian trader named Julien Dubuque secured exclusive franchise from the Sac and Fox Indian tribes to all mines west of the Mississippi River. In 1796, when this grant was confirmed by the Spanish governor of Louisiana, Julien Dubuque had succeeded in establishing a monopoly controlling the smelting and shipping of lead from the region. Until his death in 1810, Dubuque operated the "Mines of Spain" from Kettle Chief's village near the mouth of Catfish Creek, a few miles south of the present city of Dubuque. Ridden with debt, Dubuque lost financial control over the "Mines of Spain" shortly before he died, and the enterprise abruptly collapsed following his death as his creditors were unable to sustain his good relationships with their Native American hosts. Lead-mining rights in Iowa remained in a legal turmoil that lasted until 1853, when the United States Supreme Court issued a landmark decision on the ownership of the Dubuque area mines, disallowing claims based on Julien Dubuque's Spanish land grants.



The shaded area shows the extent of the Upper Mississippi Valley Zinc-Lead District.

Thus began the colorful mining history of Iowa's portion of the Upper Mississippi Valley Zinc-Lead District. The mining district, a major producer of zinc and lead ores throughout much of this country's history, covers portions of northeast Iowa, southwest Wisconsin, and northwest Illinois. Commercial mining ventures in Iowa have taken place in Dubuque, Clayton, Allamakee, Jackson, Clinton, and Jones counties. The early development of the district was spurred by the need for metallic lead, used chiefly for making lead shot. Lead production from the Upper Mississippi Valley District peaked in 1848, shortly before the gold rush to California drew many miners west in seach of greater riches. The economic life of the district was extended indefinitely when the commercial production of metallic zinc began in 1860. With its reserves greatly exceeding those of lead, zinc production from the district peaked during World War I. The mining of base metals historically has been an unstable business, and zinc production from the Upper Mississippi Valley District has waxed and waned primarily in response to economic rather than resource controls. The mines of the Dubuque area were closed in 1910, although a brief attempt was made to revive the industry in the early 1950s. Over 300 years of continuous mining activity in the Upper Mississippi Valley was broken on October 1, 1979, with the closing of the district's last operating mine at Shullsburg, Wisconsin. While it is clear that large quantities of ore remain to be extracted from the region, it is unclear if and when the enterprise will again be considered a profitable venture.

Why the Deposits are There: The zinc-lead deposits of the Dubuque area and the Upper Mississippi Valley are part of an important class of metallic, hydrothermal (formed by hot water) ore deposits that are referred to collectively as Mississippi-Valley-Type (MVT) deposits. Hydrothermal deposits are known to be derived from hot vapors escaping from cooling igneous magmas, typically formed in mountain-building regions. MVT deposits, however, occur in areas of relatively flat-lying sedimentary rocks in the continental interior, distant from any possible igneous sources. The term "Mississippi-Valley-Type" deposit was coined because several of these ore fields form major mining districts within the drainage basin of the Mississippi River. In addition to the mining district located in the Upper Mississippi Valley region, major MVT ore fields are located in southeast Missouri (Viburnum Trend District), southwest



This adaption from pioneer geologist D.D. Owen's 1839 report illustrates how residual lead was mined from the floor of natural caverns in the Dubuque area.

Missouri (Joplin District), Illinois-Kentucky (Cave-in-Rock Fluorspar District), and central Tennessee (Mascot-Jefferson City District). All of these mining districts either presently are or have been major producers of industrial base metals in the United States.

In addition to their significant economic importance, MVT deposits have remained a challenging topic for geologic research for well over a century. Though a great volume of geologic literature is devoted to observations and hypotheses on the origins of MVT deposits, many aspects of their occurrence remain controversial. Such academic pursuits are important because mineral-exploration programs are based on the geologist's conception of ore genesis.

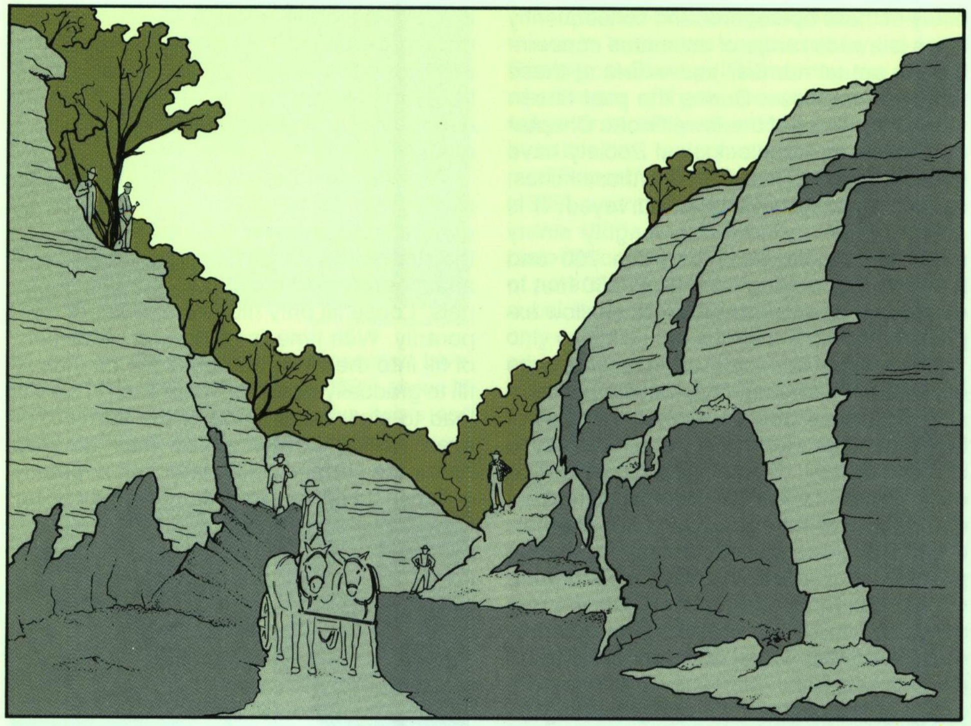
For example, in the 1890s when geologists from the Iowa Geological Survey routinely visited operating and abandoned zinc and lead mines in northeast Iowa, the prevailing theory was that the ore deposits had been concentrated by descending groundwater which dissolved minerals from the shallow bedrock and deposited them at greater depths. For several decades this misconception prevented exploration for ore deposits in areas where shale units form the bedrock surface, as the impermeability of shale was presumed to have retarded the necessary infiltration of groundwater.

Early during the Second World War, the urgent need for strategic mineral reserves spurred a collective effort by the United States Geological Survey (USGS) and the state geological surveys of Iowa, Illinois, and Wisconsin to undertake a systematic reappraisal of the geology of the Upper Mississippi Valley Zinc-Lead District. This effort spanned more than a decade and included federally sponsored exploration drilling in all three states. The drilling program led to the discovery of the two largest ore deposits ever mined in the district. In 1959, with the publication of USGS Professional Paper 309, the cumulative results of over a century of geologic research on the zinc-lead ore deposits of the Upper Mississippi Valley were described in detail. To this date, the publication remains the single most authoritative reference on the Upper Mississippi Valley District.

During the last two decades, the pace of research on MVT deposits has accelerated. Analytical precision in the laboratory has improved. Measurements of minute variations in isotopic ratios of component elements as well as analyses of microscopic bubbles trapped during the growth of MVT ore minerals have yielded much valuable information about the sources of the minerals and the hot waters from which they were precipitated. While technical disagreements among researchers still remain, a general concensus has emerged: the component elements of MVT ore deposits are derived from marine sedimentary rocks, and are carried upward in solution and deposited by hot (80° to 200°C) saline brines. These brines are similar in many respects to so-called "oilfield brines," and in fact many researchers see a link between the formation of MVT ores and petroleum deposits. Modern MVT exploration geologists are attempting to interpret the histories of past migrations of hot subsurface waters through portions of the continental interior, migrations which occurred hundreds of millions of years ago.

The metallic lead and zinc in MVT ore deposits are chemically bonded with sulfur to form sulfide minerals. The ore deposits were formed as sulfide mineral crystals precipitated from the hot brines on the walls of open, vertical fractures (cracks) in carbonate rocks below the surface. As crystal growth continued, all open space was filled, leaving a network of vertical veins of sulfide minerals in the rocks.

These sulfide mineral deposits are chemically unstable in the presence of atmospheric oxygen and water, and rapidly decay (oxidize) when the local water table is lowered below them. During the geologically recent excavation of the Mississippi River gorge, water tables in the adjacent river bluffs were lowered, and the sulfide veins in the Dubuque area were modified in an unusual fashion. No longer protected from oxidation, sulfide deposits above the water table were dissolved by infiltrating groundwater, and a network of natural



Goldthorpe's open-cut zinc mine at Durango yielded a peak production of 18 tons of "drybone" ore per day. Adapted from an 1896 photograph, Calvin collection, Department of Geology, University of Iowa.

caverns or "crevices" were formed along the older network of vertical veins. These caverns were floored by residual debris consisting of materials known to the miners as "ocher" (iron oxide formed by the decay of pyrite or iron disulfide, also known as "fools gold"), "drybone" (zinc oxides and carbonates formed by the decay of zinc sulfide), and loose encrusted crystals of galena — lead sulfide. Because lead sulfide oxidizes far more slowly than the accompanying iron and zinc sulfides, the soft debris which floored the "crevices" was filled with scattered crystals of partially dissolved galena.

When the earliest underground mining began in the Dubuque area, the "crevices" had already been in existence for tens of thousands of years, long enough to be partially filled with speleothems — the flowstone formations that commonly decorate natural cavern systems in carbonate rocks. The soft fill at the base of the open crevices was easily mined, and the galena was separated from the enclosing ocherous debris by washing and hand sorting. As excavations in the crevices extended to deeper levels and down to the water table, unoxidized sphalerite (zinc sulfide, known to the miners as "blackjack") ores were encountered. Commercial exploitation of zinc-sulfide ores was delayed until the latter half of the 19th century, when the development of steam-engine powered pumps enabled mining to take place below the water table.

Modern Impacts of Past Mining Activity: A search of the literature and the scant records pertaining to the mines at Dubuque indicates that approximately 500 mining operations were established after the year 1820. No written records are preserved for many of these operations, and consequently there is a wide range of estimates concerning the actual number and extent of these mining enterprises. During the past fifteen years, members of the Iowa Grotto Chapter of the National Speleological Society have examined approximately 100 of these mines, and 40 actually have been surveyed. It is estimated that miners dug roughly ninety miles of tunnels, sunk between 700 and 2,000 shafts ranging from 20 to 250 feet in depth, and excavated numerous shallow exploration pits.

As a general rule, production records were not kept, mines were not surveyed, nor were mine locations plotted. Only a handful of legal documents exist that pertain directly to mining activity. These record only mine ownership and a legal description of the tract on which the mine was located. Furthermore, there was no legislation establishing procedures for closing and abandoning mines. When a mine closed, the miners simply left the tunnels and shafts, and frequently left their tools, ore carts, ropes, and explosives.

The abandonment of surface workings is more difficult to evaluate because of exposure to weather and urban development. Even there, however, evidence suggests that the miners left without any attempt to close the tunnels, cap or fill the shafts, and remove surface equipment. With few exceptions, the abandoned shafts in the Dubuque mining area were left open until the timbering at their tops collapsed, partially filling the shaft. The depressions or "mineral holes" were later used as dumps for old fences, cars, garbage, or animal carcasses. With urban development in the area, these were later bulldozed over, and houses and streets were constructed.

It is no wonder that Dubuque, with its estimated 700 to 2,000 abandoned mine shafts, occasionally experiences the loss of a front yard or collapse of a street. A recent land-surface collapse along Hill Street illustrates the difficulty in precisely locating old underground mine workings, and the uncertainty in predicting areas of possible mine-related subsidence. Published records are only accurate enough to establish the close proximity of this recent collapse to the abandoned workings of the Avenue Top Mine, a mine opened in 1875, and now inaccessible for underground inspection and evaluation.

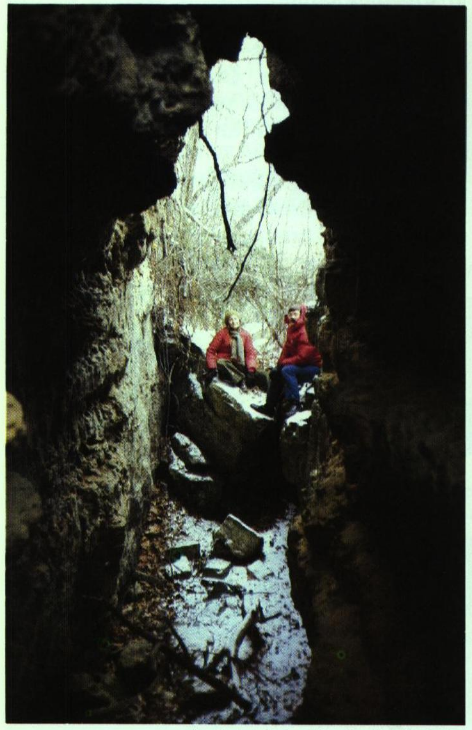
The often-used practice of filling collapsed shafts with sand, gravel, and earthen fill generally has proven inadequate. Many of the shafts were driven below the water table, and most connect extensive networks of tunnels. Loose fill only hides the problem temporarily. With time, settling and movement of fill into the tunnels causes the column of fill to gradually descend in the shaft. This will lead to slow subsidence at the surface, or even worse, hollow space may develop below the surface which later can suddenly collapse. In either case, damage may occur to overlying structures at the surface, and in the event of a sudden collapse of unsupported fill, catastrophic damage may result. While an understanding of subsurface geologic conditions is always important for the engineering design of man-made structures, this need is especially critical in areas of past underground mining.

Steve Gustafson, Dubuque *Telegraph Herald*

This road collapse along Hill Street in Dubuque occurred on November 12, 1983, and probably was caused by sinking of surface materials into the abandoned workings of the Avenue Top Mine.

John Johnson, Iowa Grotto

An ore cart discovered in the abandoned Level Crevice Mine. Before it closed in 1895, about 75 miners were employed using steam hoists and water pumps to mine below the water table.



Jim Dockal, Univ. of No. Carolina-Wilmington

This small cave, along Catfish Creek valley, is an example of cavern development in an oxidized ore deposit and may have been one of Julien Dubuque's "Mines of Spain."

Inventories of underground lead and zinc mines in Iowa were conducted by the Iowa Geological Survey (IGS) during the 1890s, when many of these operations were either active or recently abandoned. Unfortunately, to this day, maps published in the IGS Annual Report Volume 10 on Dubuque County (1899), and in later USGS reports published in the 1950s and 1960s, are the only complete descriptions available for locating areas of potential hazard from underground mine subsidence in Dubuque. These maps can only establish the approximate areas of past mine workings in relation to modern landmarks. Fortunately, the ore deposits and subsequent underground workings in the Dubuque area followed long, narrow pathways of limited width.

The occurrence of mine-related subsidence in the Dubuque area need not necessarily pose a threat to modern structures — if subsurface conditions are properly evaluated before construction. Any major construction projects in areas suspected to be underlain by abandoned mines should be preceded by engineering foundation studies. Thus, the legacy of metallic mining in the Dubuque area includes a long, colorful local history, as well as a poorly defined subsidence hazard associated with old, concealed underground mines whose precise locations are not known. □

Editor's Note: The Mines of Spain is the name given to a 1,260-acre tract of Julien Dubuque's original 290 square-mile Spanish Land Grant. This property, now in public ownership, is along the Mississippi River bluffs south of Dubuque. Its combined biological, geomorphological, geological, and cultural values are emphasized in its recent nomination to the National Park Service for designation as a National Natural Landmark.

James Dockal, a native of Dubuque and a former research geologist with the Iowa Geological Survey, is presently a faculty member of the Department of Earth Sciences at the University of North Carolina — Wilmington.

UNDERGROUND STORAGE OF NATURAL GAS

Donivan L. Gordon

A half-mile below the rolling countryside of southwest Dallas County exists a large deposit of natural gas. It is trapped in a dome-like structure within a permeable, Cambrian-age sandstone. The gas is held in place by overlying impermeable rocks and by water in the sandstone formation that confines the gas beneath the dome. This scenario is duplicated in other localities around the state — near Keota in Washington County, near Vincent in Webster County, and near Cairo and Columbus City in Louisa County. No, this is not a report on new and significant discoveries of natural gas in Iowa. Iowa is not a producer of petroleum or natural gas. Rather, these are locations where major pipeline companies actually store natural gas underground.

This method of gas storage is an innovative use of the state's subsurface geological environment. Though locating and testing such natural reservoirs a half-mile below the land surface can present some challenging geologic and engineering problems, the operational and economic incentives for doing so are significant.

The rationale for storing natural gas underground involves safety, economics, and operating flexibility. The first two factors are clear if one considers the cost, storage requirements (50 to 100 billion cubic feet), and security provisions for a facility developed at the land surface. Operating flexibility is the benefit sought for either above or below ground storage, and relates to the logistics of gas production, pipeline capacity, and meeting the delivery requirements of a seasonally fluctuating market.

Major pipelines operate at designed capacities which sometimes exceed the use rate of consumers and at other times fall short of the market demand. To obviate this problem, and to allow pipelines to operate at capacity, storage is used as a safety valve in the distribution system. During off-use seasons, the supply of gas exceeding the market demand is transferred from the pipeline to storage. During peak demand periods, gas is withdrawn from storage and used to make up for pipeline capacity shortfalls.

Iowa's underground gas-storage facilities are all "water-drive systems" — the gas is stored under pressure in water-saturated rock formations. The water is naturally confined by overlying and underlying impermeable rocks and is under hydrostatic pressures ranging from 300 to over 1,250 pounds per square inch.

The procedure for storing gas in such formations involves drilling wells into the water-bearing horizon, sealing them against possible leakage, and then forcing gas into the host formation at pressures that exceed the formation water pressure. As shown in the accompanying diagram, water is forced out of the pores in the host rock in the vicinity of the injection well. As additional wells are emplaced and injection of gas continues, a bubble develops and gradually expands beneath the "trapping structure." At each facility, a minimum required bubble is maintained by "cushion gas" — gas never withdrawn in order to protect the integrity of the bubble. This practice facilitates the ease and rate at which the "operating gas" can be injected and withdrawn. In a water-drive system, when gas is withdrawn, pressure is reduced on the injection wells at the surface which allows formation water pressure to partially collapse the bubble and force gas back to the surface.

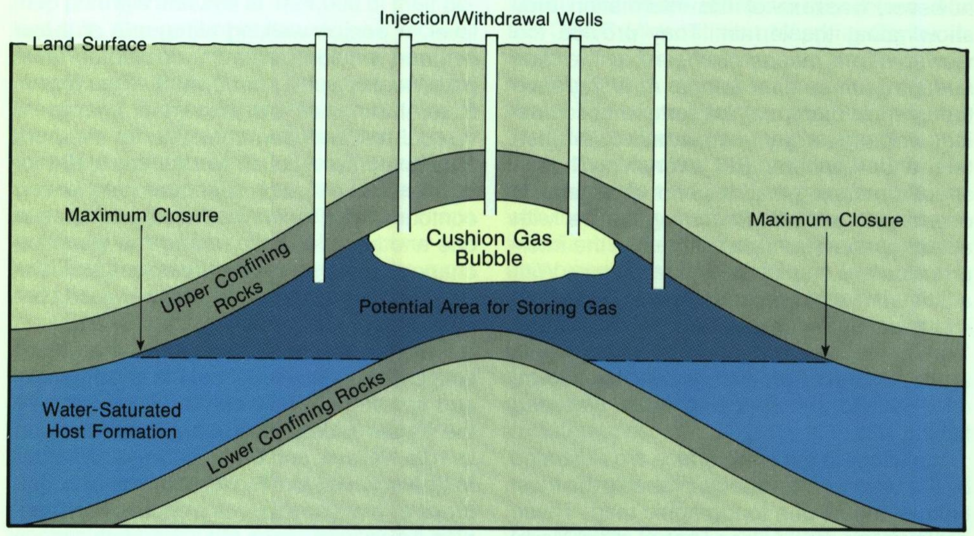
Several geologic and hydrologic constraints must be satisfied before an underground gas-storage reservoir can be established. A water-saturated host formation must be identified which has the required permeability and storage volume, and is not a source of useable quality water. The host formation must be capped by impermeable rocks to prohibit the upward migration of gas, and together they must form a closed structural configuration that provides a trap from which gas cannot escape laterally.

There are currently four underground gas-storage facilities operating in Iowa. Three (Keota, Cairo, and Columbus City) are owned by Natural Gas Pipeline Company of America, and the fourth is owned by Northern Natural Gas Company. The Vincent facility, also owned by Northern Natural, has been undergoing abandonment since 1971. Particulars on the four facilities are shown.

	Redfield	*Cairo*	*Keota*	*Columbus City*
Originally investigated	1953	1961	1962	1967
Operational date	1960	1966	1967	1970
Structure	Anticline	Anticline	Anticline	Anticline
Closure (in acres)	6,458	7,347	2,500	6,580
Capacity (billions of cubic feet)	120	150	10	140

Note: At each site, except Keota, gas is stored in two or more sandstones (primarily the St. Peter and Mt. Simon) in the same structure.

Before underground storage facilities can be placed into service they must pass geologic, safety, and operational evaluations. Final operating permission is granted by the Federal and Iowa Commerce Commissions after hearings and review of required exploration and testing. The Iowa Geological Survey has aided companies in locating potential storage structures, and has served the Iowa Commerce Commission as a consultant on underground gas-storage projects. Since 1963, permits for injection/withdrawal wells are required under Chapter 84 of the Code of Iowa which is administered by the State Geologist. □



An innovative use of Iowa's subsurface geologic environment is the underground storage of natural gas in water-saturated rock formations.

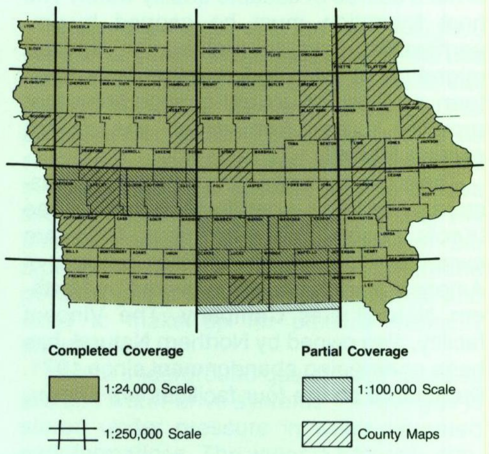
TOPOGRAPHIC MAPS OF IOWA

Raymond R. Anderson

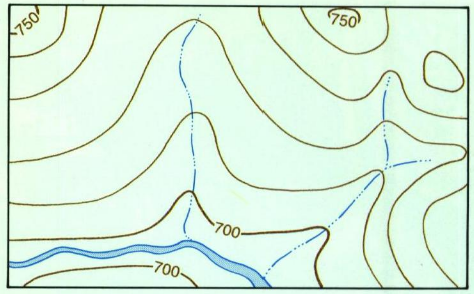
In 1984 a major milestone will be reached. Complete topographic map coverage of Iowa in the popular 7.5 minute series (1:24,000 scale) will be available. This national map series, produced and printed by the United States Geological Survey (USGS), includes 1,083 maps of Iowa. Each covers 7.5 minutes of latitude and 7.5 minutes of longitude, or an area about 9 miles in a north-south direction by 6.5 miles in an east-west direction, a total of nearly 60 square miles per map. These maps, or "quadrangles," generally are named for a town in the map area.

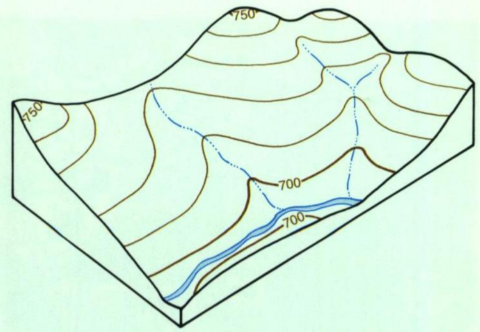
Topographic maps are similar to highway maps in that they include towns, rivers, lakes, roads, and railroads. The maps are special, however, because of the information they show about the terrain. They provide the viewer with a means of observing the land surface in three dimensions. At first glance topographic maps may be somewhat confusing, with their array of lines and colors, letters and numbers. But everything has a specific meaning that does not change from one map to another. Becoming familiar with a map of a known area will help in the interpretation of a map of unfamiliar territory. With a little concentration and some imagination, it is possible to "travel" to new places and "see", for example, how the river curves around a forest, how the hills overlook a town, or where to set up camp for a weekend fishing trip.

Variations in the land surface are illustrated by the use of contour lines, probably the most unique aspect of a topographic map. These contours are drawn along lines of equal elevation and are identified by a number signifying their altitude in feet or meters above sea



level. A person walking along one of these contours would be taking a completely level path, neither uphill nor downhill. The contour interval identifies the amount of change in vertical feet between contours; for example a contour interval of 10 feet means a 10-foot difference in elevation separates neighboring contour lines. The closer the contour lines to one another, the more rapidly the elevation changes over a given distance and the steeper the terrain. More widely spaced contour lines indicate more gradual changes in elevation, and therefore a more level landscape. With a little practice, the arrangement and spacing of these contour lines will give the viewer a clear picture of the terrain, with its hills, valleys, and drainage ways. Whether for the scientist plotting locations of rock outcrops or plant species, or a scout troop planning a weekend canoe trip, topographic maps are invaluable. They are the most accurate and detailed maps of the land surface





On a topographic map (left), contour lines are used to illustrate variations in the terrain. Contours are drawn along lines of equal elevation, and their arrangement and spacing give the viewer a clear picture of hills, valleys, and drainage patterns as they actually appear on the land surface (right).

available to Iowans today.

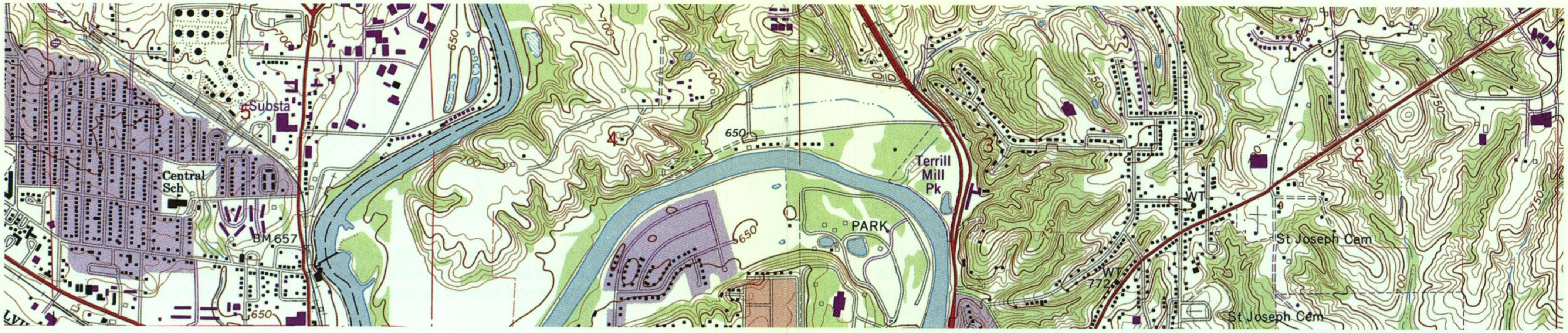
Several different topographic map series are being produced for Iowa. The index map (left) outlines those portions of the state covered by various map products. The major difference in these maps is their scale. Scale is a way of describing how much smaller the features portrayed on a map are than their actual size. Scale is usually described as a ratio of mapped size of a feature to its actual size. For example, a 1:24,000 scale map portrays features at 1/24,000 of their actual size. One unit of measure (be it inches, feet, meters, or any other measure) on the map is equal to 24,000 of the same units on the ground. The scale determines the size of the area which can be covered by a given map and the detail with which the features can be portrayed. The 1:24,000 scale maps are the largest scale topographic maps generally available in Iowa. They cover the smallest area per map, but provide the most detailed portrayal of features. The 1:1,000,000 scale maps are the smallest scale topographic maps of Iowa; they cover the largest area, but provide the least detail.

How Topographic Maps are Made

Topographic maps are the product of a long and complex sequence of procedures costing over $20,000. each and taking several years to complete. The first step is to obtain a series of aerial photographs, generally from an altitude of 10,000 feet. These photographs are produced at a scale of 1:20,000 and overlap one another so they can be viewed as stereoscopic pairs, or in three dimensions. Using these photographs, a surveying crew travels to the area to be mapped, establishes a series of control points, and erects monuments with plaques which record the exact location of each point and its elevation above sea level. A number of control points are fixed for each photograph. These field observations are then returned to the USGS Midcontinent Mapping Center in Rolla, Missouri, where each stereo-pair is mounted to a stereoscopic plotting instrument. The control points, obtained earlier in the field, are located on the photographs, and using these points of known elevation it is then possible to draw topographic contours with the plotting instrument. At the same time, woodlands, rivers, roads, marshes, quarries, and other physical and cultural features are transferred from the photographs to the map. Later, political boundaries, such as county lines and city limits, as well as place names are added; building identifications and other questions may be verified by later field investigations.

Types of Topographic Maps

7.5 Minute Series - 1:24,000 Scale: This series, described earlier, provides the most detailed topographic coverage of any maps



This is a segment of the U.S. Geological Survey, Iowa City West 7.5 minute topographic map. Accurate, detailed information about the land surface includes: elevation and configuration of the terrain (brown); rivers, ponds, and drainage ways (blue); forested areas (green); highways and cultural features (red, black); updated revisions (purple); as well as coordinates for determining precise geographic locations.

presently available for Iowa.

15 Minute Series - 1:62,500 Scale: Only thirty-five 15-minute maps were produced in Iowa, covering about 24 percent of the state. Each map covered an area of nearly 250 square miles at a scale of about one inch to the mile. They show less detail than the 7.5 minute topographic maps and have contour intervals ranging from 10 to 20 feet. The oldest of these maps was printed in 1910 and the most recent in 1967. Many are now out of print, and the USGS has no plans to reprint or expand the series.

Intermediate-Scale Series - 1:100,000 Scale: These are one of the new metric map series produced by the USGS for Iowa. These maps include contours at metric intervals (ten meters) and cover an area of 30 minutes of latitude by 60 minutes of longitude or about 2,000 square miles. Only six intermediate-scale maps have been produced, and no more will be prepared for the time being. Upon completion of the new 1:100,000 scale County Map Series, information will be used to complete the Intermediate-Scale Series in Iowa.

County Map Series - 1:100,000 Scale: The USGS and Iowa Geological Survey recently began work on a new 1:100,000 scale County Map Series. This series, initiated in part as a response to strong public demand, will ultimately lead to production of 99 maps, one for each county. These maps, also metric, probably will have a contour interval of 10 meters, and one inch on the maps will equal about 1.5 miles. The first priority group of nine maps will be completed about July of this year and will be printed in January of next year. The second group of four counties will be completed by October of this year and printed by April 1985, and two more counties will be completed in January 1985 and printed by July of that year.

U.S. NK Series - 1:250,000 Scale: The U.S. NK Series 1:250,000 scale topographic maps provide complete coverage of Iowa on 15 maps. This series was produced in the mid-1950's, and all maps were updated in the 1960's or 1970's. The 1:250,000 scale maps cover an area of 1 degree of latitude by 2 degrees of longitude (about 70 miles by 100 miles), or a total of nearly 7,000 square miles per map, usualliy with a contour interval of 50 feet.

State Topographic Map Series - 1:500,000 Scale: The 1:500,000 scale topographic map of Iowa provides complete coverage of the entire state on a single 33 inch by 48 inch sheet. The map has a contour interval of 200 feet and displays cities, lakes, rivers, highways, railroads, and federal lands as well as highlighting county lines.

International Topographic Map Series - 1:1,000,000 Scale: The state of Iowa is covered by two maps belonging to the 1:1,000,000 scale International Map of the World Series. The U.S. coverage was completed in the 1970's, but there is no projected date for completion of mapping in other areas of the world. Each map covers an area of 4 degrees of latitude and 6 degrees of longitude (about 250 miles by 320 miles). The Des Moines sheet covers all of Iowa except for the area west of 96° W longitude. This westernmost 30 miles is included on the Platte River sheet. These maps have a contour interval of 100 meters with background tints highlighting elevations.

Map Updating

The U.S. Geological Survey reviews and revises their topographic maps on a regular basis. The 7.5 minute (1:24,000 scale) maps are reviewed about every five years in metropolitan areas, about every 10 years in areas with small towns, and about every 20 years in rural areas. The 1:250,000 scale maps are revised every 10 to 15 years.

Future Topographic Maps

A number of innovations are planned for future topographic maps. These include metric mapping, digital data sets, and new map products. The use of digital (computerized) mapping procedures will allow efficient and easy updating as well as the production of "custom maps," which will display specific information requested by map-users. New map products may include contours and names on photographic base maps, satellite photography, and other combinations.

Printed topographic maps can be purchased from the Iowa Geological Survey. An *Index to Topographic Maps of Iowa,* to aid in ordering, and a price list are available on request. □

IOWA'S GEOLOGICAL PRESERVES

Jean C. Prior

Preserves are special places where pieces of Iowa's natural and cultural history are saved. They are set aside because they are links to our past; they remind us of our origins and history. They give us information, perspective, and enjoyment. They are incubators where are maintained the conditions favorable for future development of genes, data, or ideas. In Iowa, we are fortunate to have a State Preserves System which protects remaining examples of our historical, archaeological, biological, and geological roots.

Geological preserves often seem to contain the most distant and imponderable of these links; they are the farthest removed in time from events to which we can relate. In fact, the recesses of geologic time that are part of these places may be one of their most important aspects. As Claude C. Albritton, winner of this year's Geological Society of America, History of Geology Division Award, noted: "I am confident that someday the concept of geological time will be acclaimed as one of the most wonderful contributions from natural science to general thought."

In addition, geological preserves are often associated with unusually scenic localities where the terrain changes from its customary patterns and appearances. In these areas, past geologic events and processes are responsible for the present physical framework of the landscape, a framework which often supports specialized habitats and microclimates and, in turn, unique communities of plants and animals. It is in these settings that the more direct links of geologic history to our modern environment can be seen, the realization that a single place is often an interwoven fabric of several natural and cultural history interests.

Of the seventy tracts of land in Iowa now dedicated as state preserves, twenty-six are designated as geological preserves. These sites are assured the highest degree of protection that can be granted by the state, whether the land remains in private or public ownership. These preserves were selected as unique or representative landscapes and outcrops which reflect Iowa's geological heritage, from the most "recent" glacial episode of 13,000 years ago to the Precambrian Era over one billion years ago. These sites may include terrain features, fossil assemblages, important geographic reference points for specific rock formations (called "type-sections"), and other significant stratigraphic occurrences or mineral deposits.

Pat McAdams

The oldest rock formation exposed in Iowa, the Sioux Quartzite, is found in Gitchie Manitou State Preserve.

For example, the "knob and kettle" terrain found in parts of north-central Iowa is characteristic of glacial debris which accumulated in broad ridges or moraines along stagnant margins of melting ice. The Freda Haffner Kettlehole in Dickinson County is an outstanding representative of these landscapes that still show the effects of contact with glaciers. This steep-sided, undrained, circular depression resulted from the slow melting of a large, isolated, perhaps partially buried block of glacial ice which lodged adjacent to the valley of the Little Sioux River during the waning phases of the last glacial event to affect Iowa. Pollen collected from core samples taken from the bog in the bottom of this kettlehole reveal a remarkable sequence of post-glacial vegetation and climatic change, from a coniferous forest (cool, moist) to prairie grasses (warmer, dryer).

Ocheyedan Mound, one of the most recent additions to Iowa's preserves system, is another fine example of these ice-contact terrain features. This gravelly knob, known as a "kame," rises abruptly above the surrounding Osceola County landscape. Its shape and composition of stratified, or water-sorted, sediments indicates deposition by meltwater moving in contact with stagnant, wasting glacial ice. Pilot Knob in Hancock County and Caylor Prairie in Dickinson County also display the irregular, hummocky, ridged terrain characteristic of the moraines which accumulated during pauses and stagnation of glacial ice in north-central Iowa 14,000 to 12,500 years ago.

At Stainbrook Geological Preserve in northern Johnson County, an exposed surface of limestone displays parallel grooves and striations gouged into the bedrock by overriding ice during one of the earlier glacial episodes to affect the state. And at Little Maquoketa River Mounds in Dubuque County, in a terrain dominated by bedrock rather than glacial deposits, a textbook example of "stream piracy" can be observed which may have occurred in response to high meltwater discharges along the Upper Mississippi Valley. The lower course of the Little Maquoketa River originally flowed south

Dick Baker, Univ. of Iowa

The Freda Haffner Kettlehole in Dickinson County is a steep-sided, undrained depression adjacent to the Little Sioux River valley. This feature formed during melting of a large, isolated block of glacial ice about 13,000 years ago.

through the now-abandoned Couler Valley in Dubuque. The narrow divide which separated this course from the Mississippi River valley was breached, and the waters of the Little Maquoketa were pirated eastward into the shorter, more direct route to the Mississippi through what is now Peru Bottoms.

The Loess Hills, adjacent to the Missouri River valley in western Iowa, contain an internationally significant association of thick, wind-deposited silt, with striking topographic forms developed from erosional sculpture of these deposits, and native prairie and timber vegetation. Most of this loess originated between 30,000 and 14,000 years ago, as sediment released from melting glacial ice to the north was transported down the Missouri River valley in meltwater floods. During the winter seasons, when melting slowed, the exposed, debris-laden floodplain was scoured by strong westerly winds which carried silt-sized material from the valley and deposited it across the uplands to the east. The array of sharp-featured, narrow-crested, steep-sided hills and deep ravines characterizes the 220-acre Turin Loess Hills Preserve in Monona County. Other sites worthy of protection are being evaluated, and biological and cultural inventories are underway as efforts to preserve remaining natural areas intensify throughout this region.

Starrs Cave Preserve is another rich natural area within a significant geologic setting. The name Starrs Cave is given to a limestone formation deposited in warm shallow seas during the Mississippian Period of geologic time, some 325 million years ago. The picturesque bluffs along the valley of Flint Creek north of Burlington contain the type-section of the Starrs Cave Formation, that is, the site from which this rock unit was formally named and described in the geologic literature. The light-gray limestone is distinguished by small, rounded grains (oolites) and abundant fossils. The caves in the valley are characteristic features of areas where limestone occurs at shallow depths.

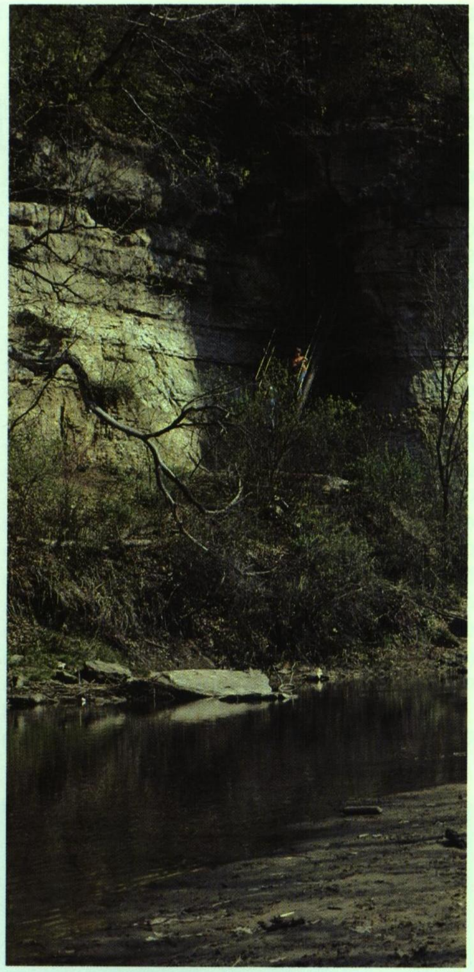
Other protected type-sections are found at the Old State Quarry Preserve in Johnson County and at the Fort Atkinson Preserve in Winneshiek County. Sites acknowledged for their historic, international reputations based on abundant, well preserved, and diverse fossil assemblages include Claybanks Forest and Bird Hill in Cerro Gordo County, where the Devonian "Hackberry Fauna" may be collected from the Lime Creek Formation.

A cluster of preserves which relate to the state's older bedrock history occurs in northeastern Iowa, particularly along a prominent landscape feature known as the "Silurian Escarpment." This leading edge of the durable, resistant Silurian-age limestones and dolomites is marked by abundant wooded bluffs, steep ravines, springs, caves, and specialized ecological niches. Brush Creek Canyon, White Pine Hollow, and Mossy Glen are good examples of preserves aligned with this geologic feature. Decorah Ice Cave and Cold Water Spring, both in Winneshiek County, are associated with the older Ordovician dolomites which occur well to the northeast of the Silurian Escarpment.

The oldest rock formation exposed at the surface in Iowa is found in Gitchie Manitou State Preserve, along the Big Sioux River valley in the extreme northwestern corner of the state. The name Sioux Quartzite was given to this formation, and its date of at least 1.2 billion years places it in the Pre-Cambrian Era of geologic time. The principal exposures of this rock, at Gitchie Manitou, were designated as the type-section of the Sioux Quartzite by State Geologist Charles White in 1870. This unusually resistant, pink-colored rock is composed of rounded, quartz sand grains compactly cemented with silica and polished by wind and weather to a glossy sheen.

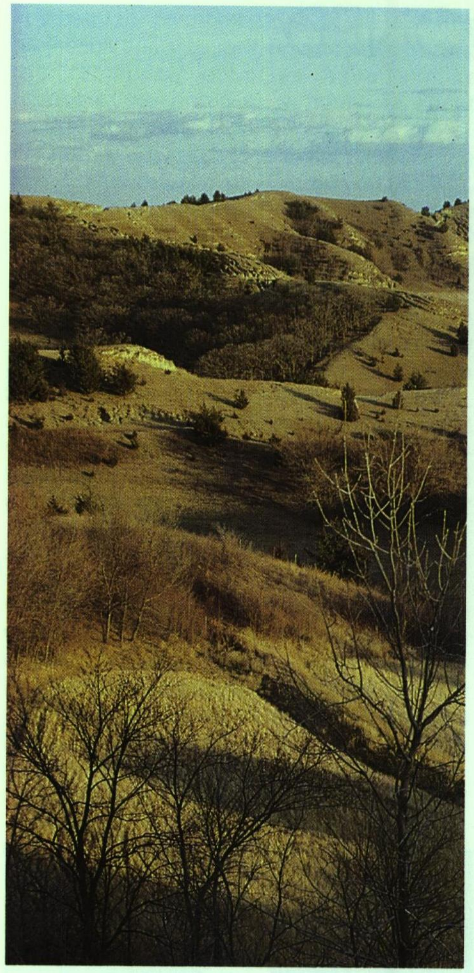
The preservation of geological features in Iowa representative of events and processes of earth history is important for developing an increased awareness and appreciation of the state's natural environment. These localities also are important to educators, for they serve as field examples of geologic features and events taught in the classroom. Professional geologists return to specific localities where sequences of strata or assemblages of fossils hold the key to important interstate correlations and interpretations. Finally, unique geologic settings often are associated with other ecological, archaeological, historic or scenic areas having scientific and educational value. At these sites, geology can be observed as an integral part of the natural environment and appreciated as a governing factor in the present distribution of plants, animals, people, and resources. □

Editor's Note: The author is currently serving a three-year appointment to the State Preserves Advisory Board.



Jean Prior

The bluffs along Flint Creek north of Burlington are the site where the Starrs Cave Formation, a Mississippian-age limestone, was first named and described.



Jean Prior

The loess hills of western Iowa contain striking topographic forms which result from erosional sculpture of thick deposits of wind-blown silt.

ABANDONED WATER WELLS

Orville J Van Eck

In the last few years we have heard increasing concerns voiced by Iowans regarding the quality of underground water supplies. A recent informal poll conducted by Iowa State University indicated that a large majority of rural residents ranked water-quality deterioration as a present or potential threat to their water supply. This problem deserves a high ranking among their concerns. Records collected over the years indeed show a decline in the quality of Iowa's subsurface water resources.

There are many reasons for this decrease in groundwater quality — increased population, changes in land-use practices, increased use of agricultural chemicals, and deteriorating and abandoned wells. This discussion focuses on abandoned wells, or those wells that have been permanently discontinued or are in such a state of disrepair that continued use is not feasible. The question is often asked, "What is so terrible about an abandoned well?" Those who work in the field of water resources have seen some of the unpleasant answers, ranging from wells used as receptacles for the overflow from septic tanks to those used for disposal of dead animals.

Far more common is the rather innocent case where well and pump system fall into disrepair through neglect. Any hole in the ground that penetrates a water-bearing zone becomes a potential avenue for pollutants to enter the groundwater. A properly constructed and maintained water well will protect the resource, but if such is not the case, then runoff from precipitation and snow melt can find ready access to subsurface water supplies without benefit of the natural filtering that occurs as water percolates through earth materials. Surface runoff contains some of most everything with which it comes in contact — human and animal waste, farm fertilizers and pesticides. Once into the groundwater system, those pollutants travel with the subsurface flow to be pumped to the surface later on by an unsuspecting user.

This situation is one of the more obvious hazards posed by abandoned wells. Less obvious is the situation where a well originally penetrated a zone of contaminated or highly mineralized water which was cased out to prevent entry of that water into the well, and the well was completed in a deeper, better quality source. Given time, well casing will deteriorate and fail. When that happens, the inferior water can enter the well and reduce the quality of the better water.

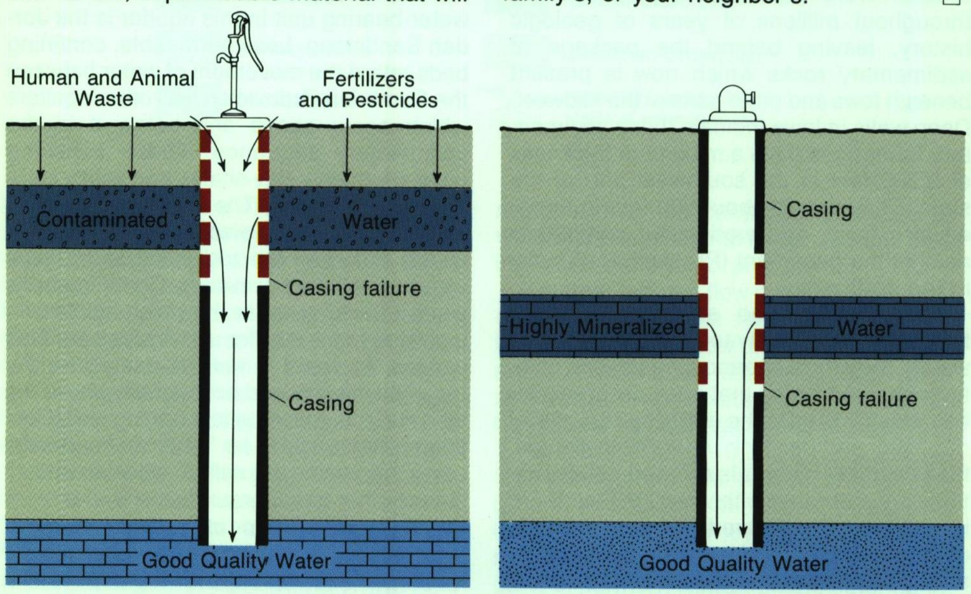
If abandoned wells pose such a threat, the next question is, "How many are there in Iowa?" We can make some estimates. The 1983 legislature directed the County Assessors to attempt to determine the extent of abandoned wells in Iowa. A postcard poll was conducted of property owners in each county. To date we have received several thousand responses and have selected four counties as representative: Allamakee, Jefferson, Audubon, and O'Brien.

In these four counties there were 7,509 rural properties in 1982. We received 3,764 responses, or about one-half. Those responding reported a total of 1,138 abandoned wells. If we assume the half that did not respond would have reported abandoned wells at the same rate, then there are twice as many, or about 2,200 abandoned wells in those four counties alone. If we take this projection one step further, and assume that the remaining counties have similar numbers, we arrive at a figure of about 54,000 abandoned wells in Iowa.

Another approach is to look at the decline in the number of farms. From 1960 to 1982, the number of farms in Iowa declined by 57,707. If we figure each farm had one well which was abandoned, we have a total of some 57,000 abandoned wells. Either approach is probably conservative because it does not consider abandoned municipal or commercial wells. Assuming there are a staggering number of abandoned wells, what should be done? Every abandoned well should be plugged from bottom to top to prevent the entrance of contaminated surface water and to prevent the mixing of water from one horizon with another. Accomplishing this can be easy and relatively inexpensive, or it can be complex and costly, depending on the depth and construction of the well. Regardless, it is important that it be done.

The objective of plugging is to fill the hole with dense, impermeable material that will prevent movement of water within the well. The most effective method is to completely fill the well with a heavy slurry of either neat cement or clean clay. Concrete mixtures are not satisfactory because separation of the aggregate and cement can occur and result in a permeable zone that permits water movement. Various plugging methods are described in two Iowa Geological Survey publications: Public Information Circular 1, *Optimal Well-Plugging Methods,* which primarily discusses larger, deeper wells; and Public Information Circular II, *Plugging Procedures for Domestic Wells,* which is devoted to smaller, shallower wells.

There is no state law that requires abandoned wells to be plugged. We must rely on an educated and conscientious citizenry to respond to a problem that endangers a resource vital to all Iowans. We urge you to be aware of the hazards that abandoned wells present. Contact a drilling contractor or the Iowa Geological Survey for advice on how to properly plug an abandoned well. To paraphrase a slogan of a few years ago — the health you save may be your own, your family's, or your neighbor's. □



Deteriorating and abandoned wells provide direct avenues for surface runoff and contaminated or highly mineralized water to enter deeper groundwater sources used for drinking.

IOWA'S REGIONAL AQUIFER SYSTEMS

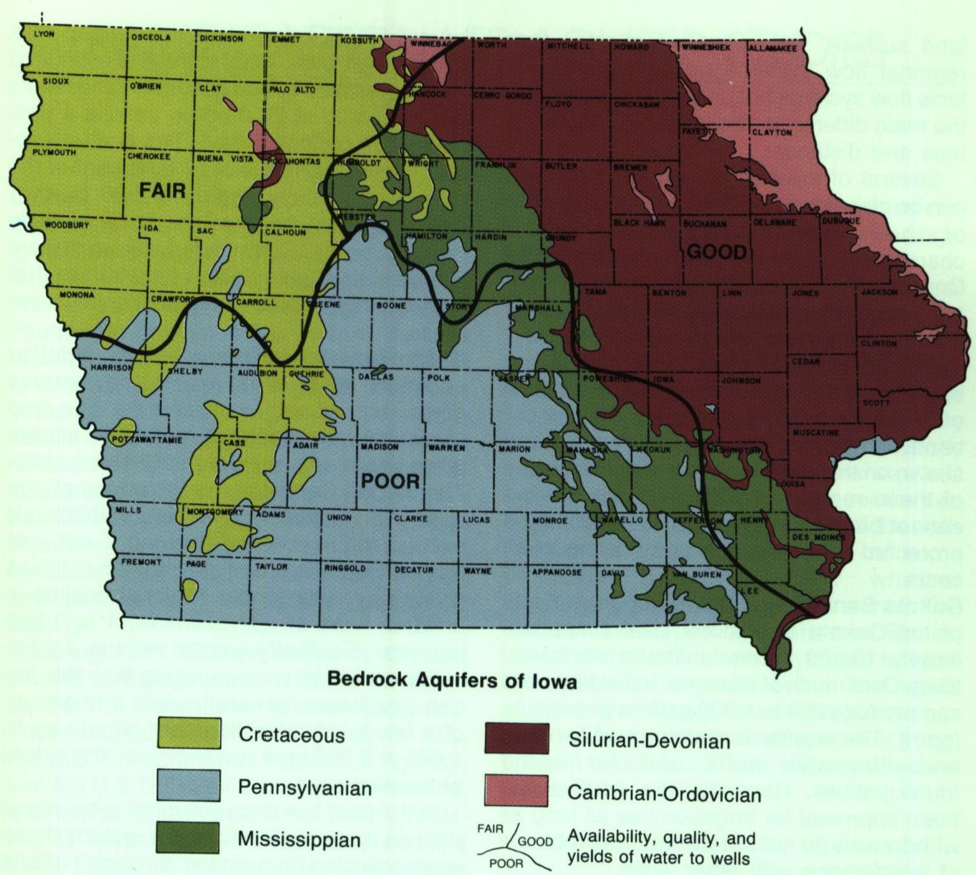
Paul J. Horick

Long before the first homesteaders broke the prairie sod, before prehistoric cultures built mounds along the Mississippi River bluffs, even before glacial ice covered Iowa, thick layers of sediment accumulated in broad basins on the floor of seas that invaded the central United States. During extended periods of geologic time these sediments were deeply buried and compacted into limestone, dolostone, shale, siltstone, and sandstone. As powerful earth stresses periodically elevated the land, the seas withdrew and erosion attacked the rocks. These processes of deposition and erosion were repeated numerous times throughout millions of years of geologic history, leaving behind the package of sedimentary rocks which now is present beneath Iowa and other parts of the Midwest. Deep wells in Iowa indicate these sedimentary formations have a maximum thickness of 5,200 feet in the southwest part of the state. They thin to about 800 feet in northeastern Iowa, and wedge out completely against the basement (Precambrian) rocks in the northwest.

These widespread sedimentary rocks have a variable ability to store and transmit water. They form enormous reservoirs of interconnected pores that soak up precipitation which infiltrates the overlying soil, glacial deposits, and bedrock. At variable depths, these surficial materials and bedrock formations are saturated with water. In fact, there is more water stored in the nation's underground reservoirs than in all the rivers and lakes combined — maybe 20 to 30 times more. It has been estimated that as much as 95 percent of the fresh water available in the United States is stored in the rocks of the earth's crust. The permeable rock formations, such as sand and gravel, sandstones, and creviced limestone or dolostone, that yield water to wells are called aquifers. Regional aquifers extend over large areas, usually including parts of several states. A regional aquifer system may include several geologic units and more than one water-bearing zone.

One of the most prominent regional aquifer systems is the Cambrian-Ordovician aquifer of the north-central United States, including parts of Illinois, Indiana, Iowa, Minnesota, Missouri, and Wisconsin. The main water-bearing unit in this aquifer is the Jordan Sandstone. Less permeable, confining beds retard the movement of water between the Cambrian-Ordovician and other aquifers which occur above and below it in the sedimentary sequence. These confining beds are mainly clay-shales and tightly compacted limestones. The microscopic openings in these rocks also may be filled with water, but they are too small to transmit water to wells economically. Confining beds serve a useful purpose, however, by containing water in the aquifer under pressure. This causes the water in wells to rise above the top of the aquifer and occasionally above the land surface, resulting in a flowing well. Confined water is said to be "artesian" and wells using this source are called "artesian wells." On the other hand, groundwater that is open to the atmosphere, or unconfined, is under "water-table" conditions, and water in these wells will not rise above the top of the aquifer.

Groundwater is always in circulation from



Bedrock Aquifers of Iowa

a recharge area to a discharge area. The source of much of the water in an aquifer is within a surprisingly short radius of a few tens of miles. The water is derived from surface infiltration and moves only a short distance through the soil and rock to a point of discharge, such as the floor of a nearby stream. Recharge which moves into deeper flow paths or into a deeply buried, confined aquifer may flow considerably longer distances before discharging. This deep confined flow is usually spoken of as regional flow as opposed to shallow local flow. Regional flow is relatively unaffected by direct recharge from the surface, whereas there is a close relationship between surfacewater and groundwater in local flow systems. It is the contribution of groundwater, for example, that keeps streams flowing when there is no precipitation.

Because regional flow paths cover greater distances than local flow paths, it takes longer for regional flow to reach a discharge point. It has been estimated that water pumped from wells completed in the Jordan Sandstone in southeast Iowa at depths of 1,800 feet is at least 10,000 to 12,000 years old, dating from the time it entered the ground in southern Minnesota through its long subsurface journey southeastward. In northeast Iowa, Minnesota, Wisconsin, and parts of northern Illinois, on the other hand, most of the flow in the Jordan aquifer is local flow because the sandstone is close to the land surface. All evidence indicates that regional flow systems perform much like local flow systems but on a larger scale, with the main differences being depth, pressure, time and distance.

Several of the bedrock aquifers of Iowa can be classed as regional aquifers because of their wide distribution and flow characteristics. The most prominent are the Cretaceous (Dakota) sandstones, Mississippian limestones and dolostones, Silurian-Devonian limestones and dolostones, and Cambrian-Ordovician (Jordan and St. Peter) sandstones and dolostones. The distribution of these bedrock aquifers, as they occur beneath the state's glacial deposits, is shown on the accompanying map. The value of these regional aquifer systems to Iowa cannot be over-emphasized. They must be protected from pollution and misuse at all costs.

Dakota Sandstone: The major area of use of the Dakota Sandstone covers approximately 10,600 square miles in northwest Iowa. Over much of this area, individual wells can produce 250 to 1,000 gallons per minute (gpm). The aquifer is widely used for farm and domestic wells and for some municipalities. Recently, the aquifer has been approved for irrigation use as long as withdrawals do not create serious problems of interference with other wells.

Mississippian Limestone and Dolostone: The Mississippian aquifer underlies a large part of the state, but its major area of use occurs along the narrow outcrop belt of roughly 7,100 square miles. The most productive wells occur in the north-central outcrop area where the transmissivity of the rocks is highest. Yields of 100 to 200 gpm are common, and as much as 500 to 1,000 gpm have been obtained where wells intersect large crevices or solution cavities. It is estimated that 10 to 12 trillion gallons of water are stored in the aquifer in this area. For the aquifer as a whole, approximately 6.2 billion gallons a year are withdrawn (17 million gallons a day), with 70 percent coming from the north-central outcrop area.

Silurian-Devonian: This aquifer is a significant source in 30 percent of the state (16,000 square miles), primarily in the outcrop area of northeast Iowa. Total storage is estimated to be at least 20 trillion gallons. Withdrawals are estimated at 27.8 billion gallons a year (75 million gallons a day). The aquifer supplies the water needs of 17.5 percent of the state's population. Yields of 500 to over 1,000 gpm may be developed from wells in the outcrop area, particularly along stream valleys. However, yields of less than 100 gpm are more typical of the aquifer in upland areas.

Cambrian-Ordovician: This aquifer underlies all of Iowa except the extreme northwest and southwest corners. The area of maximum use consists of 34,000 square miles in the eastern two-thirds of the state. The Jordan Sandstone is the principal producing unit in this system. Total withdrawals exceed total recharge, leaving a net loss from artesian storage of about 5.5 billion gallons per year and a regional decline in artesian head of approximately 1 to 3 feet per year. Evidently we are mining Jordan water. Individual wells pumping from the Jordan Sandstone generally yield a minimum of a few hundred gallons per minute up to 1,000 or 2,000 gpm depending on the extent of development.

In the past few decades large amounts of data on these regional aquifer systems have been collected through the combined efforts of the Iowa Geological Survey and the U.S. Geological Survey with the assistance of Iowa well-drilling contractors. On-going research has generated several reports that summarize the geology, hydrology, and quality of water in these systems. The Silurian-Devonian aquifer report was published this year. Previous reports have been issued on the Mississippian, Jordan (Cambrian-Ordovician), and Dakota aquifers. Copies of these regional aquifer studies can be purchased from the Iowa Geological Survey. □

KARST-CARBONATE AQUIFER STUDIES

George R. Hallberg

The past two issues of *Iowa Geology* included reports on continuing Iowa Geological Survey (IGS) investigations of groundwater quality in the karst-carbonate aquifers of northeastern Iowa. These studies involve portions of the regionally important Silurian-Devonian and Cambrian-Ordovician aquifers, described in the preceding article. In contrast to evaluating regional properties of the aquifers, these studies focus on local details of the hydro-geologic framework and on the relationships between landuse activities and groundwater quality. Our work has shown that groundwater in these aquifers is being contaminated by agricultural chemicals — particularly nitrates and pesticides — in specific geological settings.

During 1983, IGS expanded its detailed studies to include portions of the Devonian aquifer in Floyd and Mitchell Counties. These studies were funded jointly by IGS, the U.S. Environmental Protection Agency, and the U.S.D.A. Soil Conservation Service, with the cooperative services of the University of Iowa Hygienic Laboratory and the Iowa Dept. of Water, Air, and Waste Management.

The data collected in these counties corroborates and amplifies our earlier findings. Although runoff into sinkholes contributes to the contamination of groundwater in local areas, simple infiltration delivers most of these chemical contaminants to the groundwater. The highest concentrations of nitrates and pesticides found in wells in Floyd and Mitchell Counties occur in areas marked by high infiltration and *no* sinkholes. The study showed that in areas where there was less than 50 feet of glacial deposits over the carbonate bedrock, 70 to 80 percent of the wells sampled showed the presence of some pesticides during the year, whether sinkholes occurred in the area or not. The commonly used pesticides Atrazine, Bladex, Lasso, Sencor, Dual, and Dyfonate have all been detected in groundwater. The details of these studies will be included in various technical reports, and further work will continue in cooperation with state and federal agencies. □

NEW UNDERGROUND COAL MINE

Paul E. Van Dorpe

Superior Coal Company is operating Iowa's newest, and currently the state's only, underground coal mine. Owned by Iowa Coal Mining Company, and opened in October 1983, the mine is located in Monroe County about five miles southwest of Lovilia. The mine is a "room and pillar" operation, with a slope entry to depths of 100 to 150 feet. Its height varies with the thickness of the coal seam, from three to seven feet. At full capacity, Superior expects to produce 200,000 tons annually. □

Paul Van Dorpe

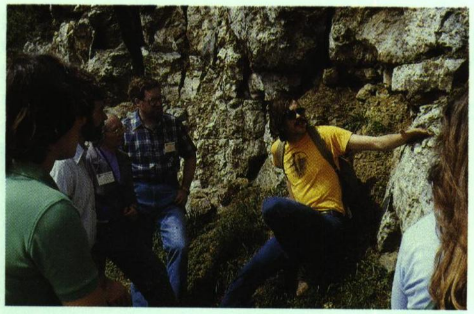
FIELD FORUMS

Bill J. Bunker

Geology is a field science. It relies heavily on data collection and model-building, interpretation and reevaluation. Field trips are an important part of this process. They provide opportunities for consultation and communication regarding observations, research progress or conclusions. Iowa Geological Survey (IGS) geologists often are asked to discuss their research activities with others at the national, regional, or state level. This frequently is accomplished in conjunction with annual meetings and field trips of various professional organizations.

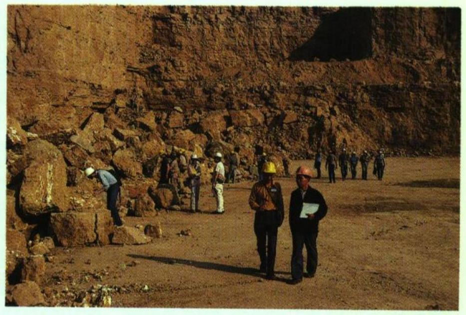
In September 1983, the Great Lakes Section of the Society of Economic Paleontologists and Mineralogists held their 13th Annual Field Conference in Iowa. The focus of this meeting was the Galena Group carbonate rocks, a formation widespread in the central midcontinent, but exceptionally well exposed across much of northeastern Iowa. These Ordovician rocks constitute many of the scenic bluffs and cliffs near the Mississippi River valley. They also exhibit sinkholes and cavern systems characteristic of solutional or karst development and are important as a local source of groundwater to wells.

The Geological Society of Iowa, an organization which represents the professional geologic community in Iowa, coordinated two field trips in 1983 which focused on IGS research in the karst regions of northeastern and north-central Iowa. Their annual spring field trip, held in association with the Iowa Academy of Science meeting in Decorah, examined a series of Devonian exposures in southwestern Winneshiek and northern Fayette counties. This trip was lead by Bill Bunker and Brian Witzke of the Survey's Stratigraphy and Economic Geology Division, and Gilbert Klapper of the University of Iowa, Dept. of Geology. The purpose of this trip was to examine the evidence for a buried Silurian escarpment, similar to the Silurian escarpment visible in the northeastern Iowa landscape today, and its effect on Middle Devonian sedimentation in Iowa. The establishment of a new Devonian stratigraphic framework in this region has proven beneficial to recent studies of the Devonian aquifer system in north-central Iowa. The fall field trip, lead by Michael Bounk of IGS, took a closer look at the present Silurian escarpment and its associated karst system in Fayette County. Much of this karst is expressed as springs and caves at the base of the escarpment and as sinkholes in the upland areas.



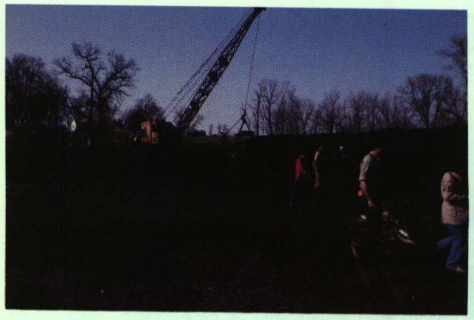
Kay Irelan

Brian Witzke (IGS) explains characteristics of an outcrop of the Cedar Valley Limestone during a tour of geological points of interest on the University of Iowa campus.



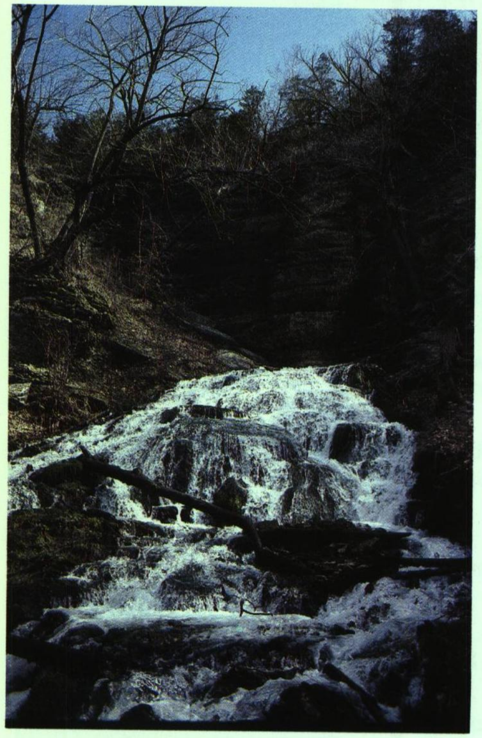
Bill Bunker

Rocks of the Galena Group are examined in a Dubuque Stone Company quarry by members of the Great Lakes Section, Society of Economic Paleontologists and Mineralogists.



Ray Anderson

Fossil and modern plants are the subject of this stop at a Muscatine County peat bog within the Lake Calvin Basin.



Art Bettis

Dunnings Spring in Winneshiek County flows from a vertical fracture in the limestone. Sinkholes within the drainage basin above this spring demonstrate the direct connection between surface and groundwater systems in northeast Iowa.

The 1984 Annual Meeting of the Iowa Academy of Science was held in Iowa City, and Survey staff were active in program and field-trip planning. Two symposia provided opportunities to communicate information related to the state's geology: "New Developments in Iowa Geology — A Review by Geologic Systems" and "Iowa's Loess Hills." The Survey also sponsored a walking tour of geological points of interest on the University of Iowa campus, allowing participants to examine Devonian, Pennsylvanian, and Pleistocene strata exposed along the Iowa River valley. A complementary trip to examine equivalent strata at Conklin Quarry, along the north edge of Iowa City, was hosted that same weekend by the Geological Society of Iowa.

Recently, an effort has been underway to encourage interdisciplinary consideration of natural science issues in Iowa. The Iowa Natural History Association represents this blend of interests among natural scientists in the state. Interdisciplinary examination of field relationships promotes understanding of the basic geological processes and materials which compose the landscape, as well as the plant and animal communities which occupy distinctive habitats based on the geological framework of the landscape. Understanding this interaction of the geological and biological environments, as well as man's prehistoric and historic cultural evolution within these environments, can influence the design of future research projects as well as promote information exchange among scientists working in the same geographic area from different professional perspectives. Regions examined in the past two years were the Upper Iowa River valley between Decorah and New Albin, and the Lake Calvin Basin, a complex alluvial plain southeast of Iowa City. □

SEARCHING FOR IOWA OIL

Raymond R. Anderson

The search for oil and gas in Iowa continued in 1983 and early 1984 with over 20 major oil companies and independents actively investigating the hydrocarbon potential of the state. Exploration interest is equally divided among three potential petroleum provinces.

In southeast Iowa, the exploration targets are two discontinuous sandstone units, the basal-Devonian and the Starved Rock (Ordovician), ranging in depths between 750 and 1,500 feet. The second area of exploration is the Forest City Basin, which includes portions of southwest Iowa. Oil here is sought from the Pennsylvanian Cherokee sandstones at depths up to 1,700 feet. The third potential province is the deep Keweenawan basins in central and southwest Iowa. Hydrocarbons may have formed in Precambrian source rocks between 1,500 and 40,000 feet below the surface. Exploration in this province is energetic, with over 300,000 acres already under lease, and four deep exploration wells now being drilled. Examination of the data collected during a seismic-exploration program conducted last year in central and southwest Iowa by KEWA Exploration Co. of Denver, led them to expand the study this year into Cerro Gordo County. □

SELECTED SURVEY PUBLICATIONS

Buckmiller, R.C., and Karsten, R.A., 1983, *Estimated Water Use in Iowa, 1980:* IGS Miscellaneous Map Series 9, maps with text.

Cumerlato, C., 1983, *Data Collection and Processing Parameters for the Malvern Seismic Reflection Traverse:* IGS Open-File Report 83-2, 16 p.

Forest City Basin and Adjacent Regions of Iowa, Kansas, Missouri, and Nebraska; Scale 1:500,000. Two 1983 additions include: *Mineral Resource Map* and *Deep Well and Oil-Gas Field Location Map.*

Hallberg, G.R., Hoyer, B.E., Bettis, E.A., and Libra, R.D., 1983, *Hydrogeology, Water Quality and Land Management in the Big Spring Basin, Clayton County, Iowa:* IGS Open-File Report 83-3, 191 p.

Hallberg, G.R., Libra, R.D., Ressmeyer, G.G., Bettis, E.A., and Hoyer, B.E., 1984, *Temporal Changes in Nitrates in Groundwater in Northeastern Iowa:* IGS Open-File Report 84-1, 10 p.

Hatch, J.R., Avcin, M.J., and Van Dorpe, P.E., 1984, *Element Geochemistry of Cherokee Group Coals (Middle Pennsylvanian) from South-Central and Southeastern Iowa:* IGS Technical Paper 5, 108 p.

Horick, P.J., 1984, *Silurian-Devonian Aquifer of Iowa:* IGS Miscellaneous Map Series 10, 4 maps with text.

Munter, J.A., Ludvigson, G.A., and Bunker, B.J., 1983, *Hydrogeology and Stratigraphy of the Dakota Formation in Northwest Iowa:* IGS Water Supply Bull. 13, 55 p.

Prior, J.C., Baker, R.G., Hallberg, G.R., and Semken, H.A., *Glaciation:* reprinted from *Iowa's Natural Heritage,* (Ed. Cooper) 1982, p. 42-61.

IGS ORGANIZATIONAL STRUCTURE