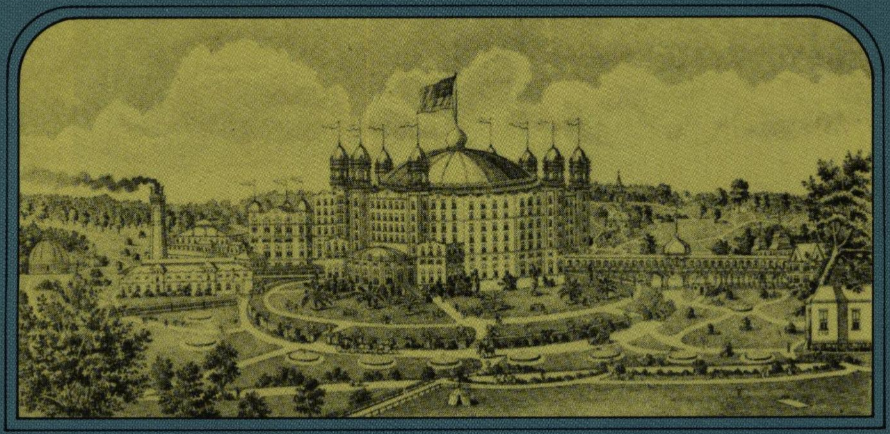

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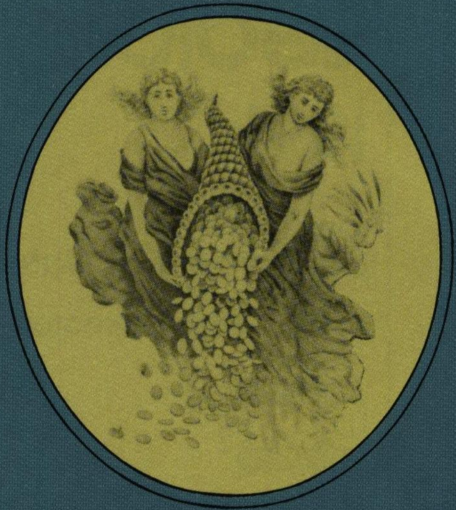

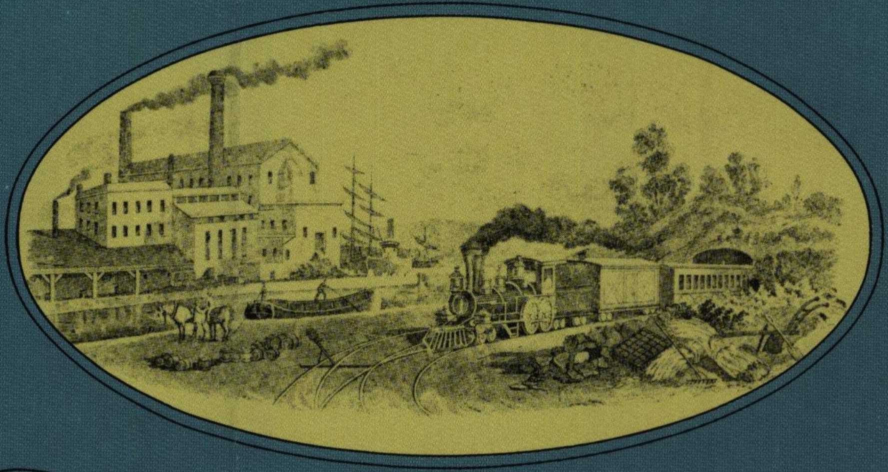

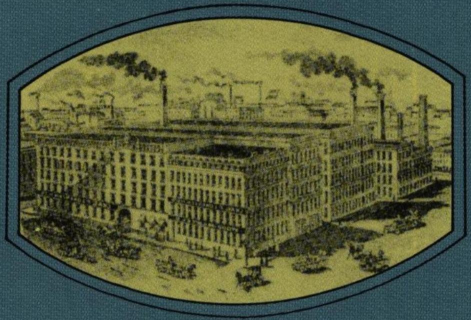

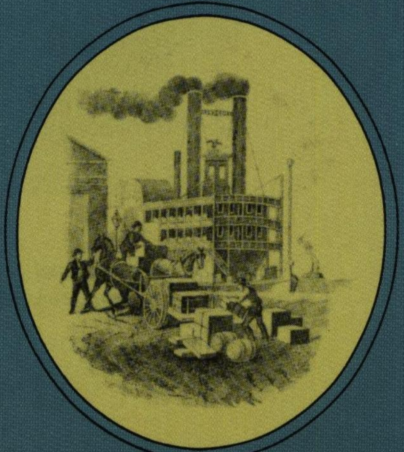

Iowa Geology 1991

Iowa Department of Natural Resources

Iowa Geology 1991

Iowa
Department of Natural Resources

Larry J. Wilson, Director

Geological Survey Bureau
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Donald L. Koch
State Geologist and Bureau Chief

COVER:

These crisp images and designs appear on a variety of certificates engraved by the American Lithographing and Printing Company of Des Moines on lithographic limestone quarried at Lithograph City in Floyd County. They were published as a series of plates in Clement Webster's 1915 issue of *Contributions to Science* to illustrate the quality of this Iowa stone for printing.

Cover design by Patricia Lohmann

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

Printed on Recycled Paper

CONTENTS

STATE GEOLOGIST'S VIEWPOINT

Questions about when the geological survey of Iowa will be complete always bring a smile to staff geologists. If one look was enough, the work would have been completed about 1870. As the state's population increased, the need for geological and groundwater resources also expanded. And with more intensive use of Iowa's land, inevitable environmental impacts have occurred. Because resources beneath the ground are not uniformly distributed in quantity or quality, and because competition for their use is increasing, accurate up-to-date information is essential to assessments of resource availability and environmental protection.

This need for increasingly detailed geologic and hydrologic information about various deposits that underlie the state means our staff is continually gathering and interpreting new information as well as using new methods and techniques to examine old information. As we respond to the resource issues and environmental problems that confront us today, we also try to anticipate questions and problems that will arise in the future. To that end, it is important to identify where our information gaps occur. What are today's pressing, unanswered questions about Iowa's geology and what needs to be done to solve them?

This issue of *Iowa Geology* addresses the first in a series of these questions. For many years, geologists have been aware of the so-called "salt and pepper sands" of western Iowa. This descriptive name was given to these distinctive deposits by area well drillers who first encountered them. The deposits occur in a portion of Iowa where dependable bedrock aquifers are absent or are overlain by more than 300 feet of glacial materials. Little is known of the potential for groundwater resources within the sands and gravels that accompany these thick, widespread glacial-age deposits. This gap in our knowledge was apparent during preparation of the new map *Groundwater Vulnerability Regions of Iowa* which is described in this issue. To answer questions about the distribution, composition, and water-bearing characteristics of the enigmatic salt and pepper sands, as well as determine the presence of buried-channel aquifers in this part of the state, will require precise subsurface investigations. Research drilling, described in another of this issue's articles, is part of the solution to the geologic and hydrologic puzzles of western Iowa and the need to locate dependable groundwater supplies. It is a vital tool in finding answers to the fundamental questions about Iowa's geology.

Donald L. Koch

Donald L. Koch
State Geologist and Bureau Chief

ENERGY, ECONOMICS, AND THE ENVIRONMENT

George R. Hallberg

In 1989, Iowa received the top award for "Food Safety" as one of five states honored by Renew America, a national group that recognizes state environmental efforts. In 1990, Iowa won the "National Energy Program Innovation Award" from the National Association of State Energy Officials. In 1991, Iowa's Model Farms Demonstration Project was cited in the "Environmental Success Index" by Renew America as a model environmental program. Surprisingly, these diverse awards all relate to initiatives stemming from Iowa's 1987 Groundwater Protection Act and all are tied to an innovative concept: Iowa's "Integrated Program for Energy Conservation and Environmental Protection." This program linking energy and environmental considerations results from Iowa's precedent-setting plan to use 17.5 million dollars of oil-overcharge funds to implement energy-related elements of the state's Groundwater Protection Act.

Many of today's major environmental issues are closely linked to energy consumption. For example, air-quality problems are tied to the energy consumed by automobiles and power generation. Energy use is also related to such issues as waste management, water quality, and even sustainable agriculture. Other energy-consumptive activities include remedial clean-up and water treatment associated with waste disposal problems and groundwater contamination. As we realize the full costs of waste disposal, the programs to implement waste reduction, recycling, and energy-resource recovery become economically viable. In the agricultural sector, the contamination of water supplies from nitrates and pesticides is a serious problem. Nitrogen fertilizers and pesticides are derived from energy stocks and now constitute the largest component of energy consumption in row-crop production.

The Iowa Department of Natural Resources (DNR) oversees expenditure of the oil-overcharge funds, but many agencies, universities, and local governments are involved with implementing the statewide demonstration projects and public education programs that bring about reductions of energy-consumptive inputs in environmentally related areas. Agricultural programs, such as the Integrated Farm Management Demonstration Project (IFM), the Model Farms Demonstration Project, and the Big Spring Basin Demonstration Project, have developed land-management demonstrations in every county, involving over 1,000 private farmers. These programs are all joint ventures among the Iowa Department of Agriculture and Land Stewardship, the Iowa State University Extension, and the DNR.

Waste-to-energy programs have cost-shared regional and community demonstration projects in waste-reduction, recycling, and energy recovery in nearly half of Iowa's counties. Energy resource programs have promoted development of biomass-energy and refuse-derived fuel demonstrations, as well as new automated techniques for energy-resource assessment and planning. DNR's Waste Management Authority has used funds from landfill fees to help local communities develop waste-reduction programs.

These programs have received awards not just for innovation, but because they are producing results (see right). The Integrated Crop Management Project (ICM) provides consultative services, ranging from the new nitrogen soil testing to pest-management scouting, to help farmers improve management and profitably reduce their use of fertilizers and pesticides. This successful project, in effect, substitutes service sector employment for the blanket use of chemicals and energy. These producers not only have found a rapid payback, but have also reduced their effective energy consumption. The total energy savings from fertilizer and pesticide reductions more than equalled the total fuel directly consumed by these farms for field operations.

Solid-waste reduction and recycling also have major energy benefits. In addition, there is significant potential in waste recovery and biomass for energy generation in Iowa. Through Iowa's Integrated Program these alternative and renewable sources of energy will play a more important role in Iowa's energy future, thereby reducing dependence on imported energy sources.

The Integrated Program's demonstration aspects are functioning pilot programs implemented, for example, by local waste-management authorities or on private operating farms. Many program elements, such as the ICM project and the waste-management demonstrations, are designed to evolve from these pilot demonstrations to operational phases and be adopted as private-sector businesses or local public-sector enterprises. This component of transferability was designed into many phases of the program to facilitate its long-term implementation.

The Iowa Integrated Program for Energy Conservation and Environmental Protection is one of the first of its magnitude in the nation to recognize that comprehensive energy conservation and environmental protection must be integrated. This program emphasizes that, for maximum efficiency, policies and strategies dealing with the management of energy and energy-related resources must be positioned at the top of the hierarchy with other environmental protection efforts. □

PROGRAM FACTS

- *An estimated 14 million Btu's* are saved for every ton of paper recycled. Recycling of aluminum reduces energy use by 96% compared to new production.*
- *Statewide refuse-derived fuels could supply 12 billion Btu's/year. Crop biomass could potentially supply 230 trillion Btu's/year for Iowa.*
- *The amount of fertilizers and chemicals used on the average 160 acres of corn in Iowa is the equivalent of over 1 billion Btu's.*
- *Statewide, ag-chemical and fertilizer applications consume the equivalent of 90 trillion Btu's/year.*
- *In the past 2 years, 50 farmers (ICM Project) increased their net return by over $500,000/year.*
- *In 1989 ICM farmers reduced nitrogen fertilizer use by 240,000 lbs, the equivalent of nearly 8 billion Btu's.*
- *240,000 lbs of nitrogen not put into the environment is the surest form of pollution prevention.*

*127,654 Btu's are the energy equivalent of 1 gallon of automotive gasoline.

PESTICIDES IN IOWA PRECIPITATION

Brenda K. Nations

Iowans know the importance of rainfall, especially after the droughts and floods of the past several years. The quality of this rainwater became an issue when studies in other states showed evidence of atmospheric pollutants being deposited via rainfall, especially in the Great Lakes area. Later studies in both the midwest and along the east coast showed that agricultural pesticides commonly occur in rainfall, especially during the summer months. In 1987 the Geological Survey Bureau of the Iowa Department of Natural Resources began a study to determine if rainfall in Iowa contained any agricultural chemicals.

Iowa is an ideal setting for examining the presence of pesticides in rainfall. Most of the state's land is farmed, and it is estimated that more pesticides are used here than in any other state. Pesticides already have been detected in the state's groundwater and surface water, and because these chemicals volatilize (or vaporize) into the atmosphere after being applied, a study of rainwater is necessary to a more complete understanding of their transport and fate in the environment.

Three different sites were chosen for taking rainfall samples. Two of these sites are rural: the Big Spring basin in northeast Iowa (Clayton County) and the Bluegrass Creek watershed in west-central Iowa (Audubon County). The third site is in urban Iowa City (Johnson County). Between 1987 and 1990, samples were taken after each rainfall and were analyzed for the 18 most common pesticides used in Iowa. Rainfall samples were collected throughout the year, and snow was occasionally sampled during the winter months.

Fourteen pesticides were detected in rainfall samples during the three-year period. Ten of these pesticides were herbicides, and four were insecticides. The most commonly detected herbicides were atrazine, alachlor, metolachlor, and cyanazine; common product names for these chemicals are Aatrex, Lasso, Dual, and Bladex. These results correspond directly with the high use of these farm chemicals in Iowa. The concentrations were usually small, with most detections under 1 ppb (parts per billion), but larger amounts, up to 40 ppb, occasionally were detected. Concentrations of pesticides in rainwater were usually less than the drinking water standards set by the U.S. Environmental Protection Agency for all of the chemicals detected.

Pesticide detections in Iowa's precipitation clearly showed a seasonal trend. The agricultural chemicals were found in almost every rainfall from mid-April through July, the same months when pesticides have the greatest potential of volatilizing into the atmosphere. The appearance of these chemicals as early as mid-April, before farmers in Iowa begin applying them, may be the result of volatilization of carry-over residues on fields because of the warming soils, or perhaps the result of transport from southern areas where these chemicals are applied at earlier dates. Detections decrease after July, when they are no longer applied, and only occasionally do pesticides occur in fall rains. No detections occurred during the winter months, and no pesticides have been found in snow.

Jean Prior

Pesticides were detected in nearly every rainfall from mid-April through July at three sampling sites across Iowa between 1987 and 1990. The land-applied chemicals vaporize into the atmosphere where they mix with precipitation.

Most of the pesticides found at the two rural sites, Big Spring and Bluegrass Creek, were also found in rainfall at Iowa City. This suggests that pesticides are being transported to areas where they are not applied. Detections in Iowa City, however, were not as high as in the rural areas, indicating that concentrations become lower with increasing distance from the source. Detections at the two rural sites were similar to each other, except that the western site had herbicides not detected at the other two sites, which related to local use of those products.

Pesticides are present in rain because they volatilize, making them available in the atmosphere to combine with precipitation. Each chemical has properties that affect how long it will exist in the environment before breaking down, as well as how easily it vaporizes. All these properties play a role in the occurrence of each pesticide detected in rainfall. Also, weather conditions such as temperature, wind, and humidity at the time of application affect how much of the pesticide volatilizes and is transported.

Studies have shown that pesticides can travel great distances in the atmosphere, as they have been found in such remote areas as the West Indies, the Canadian Arctic, the Swiss Alps, and Pacific Ocean islands. Pesticides detected in Iowa are most likely applied within the state or perhaps surrounding states. It is not yet known if the high usage of these chemicals in Iowa and the midwest accounts for any of the atmospheric movement to more distant locations.

Although the concentrations of pesticides found in precipitation are probably not enough to pose a health risk, it is important to realize that these chemicals are being transported in a variety of ways within the environment. Iowans, concerned about the impacts of agricultural chemicals on their environment, are looking for methods to reduce high pesticide usage. These studies on the fate of pesticides in the environment will bring us closer to an understanding of how to use these chemicals while maintaining or improving environmental quality. □

RESEARCH DRILLING:
KEY TO THE SUBSURFACE

Donivan L. Gordon

During the earliest geologic mapping projects in Iowa, geologists had to rely completely upon rocks exposed at the land surface. From outcroppings in the northeastern corner and other scattered areas of the state, a geologic sequence of strata was established. The oldest rocks were found to occur at the surface in northeast Iowa, and progressively younger rocks were seen toward southwest Iowa. The entire sequence of rock units was determined to be sloping downward to the southwest. However, with most of the landscape mantled by glacial deposits, other details of the underlying geology could not be well defined.

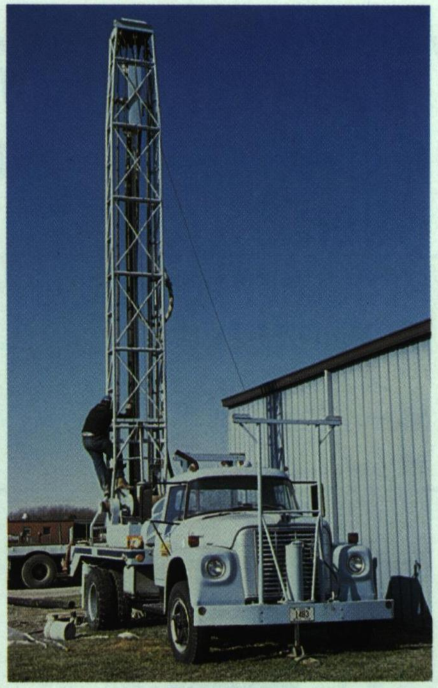
With the advent of new drilling technology and the need for increased quantities of potable water, Iowa communities began drilling wells for their water supplies. Drill cuttings from these wells became available for geologists to examine and opened an era of subsurface investigations that continues today. Beginning in the early 1930's, the Iowa Geological Survey instituted a program of gathering well cuttings from cooperating water-well contractors around the state. Drillers were asked to voluntarily save samples during drilling, and in turn they were provided with notebooks for registering facts about the wells and sample bags for saving drill cuttings. Over the years, this program has enabled geologists to log over 20,000 wells. Essentially, this cooperation has provided the data to portray the fundamental features of Iowa's subsurface geology. However, the information alone is not enough to provide the detail required in examining specific geologic or hydrologic problem areas.

Specific geologic investigations often require much more detailed subsurface information than available from conventional sources. In these situations the Bureau's research drilling capabilities come into play, with projects designed to maximize the amount of information that can be obtained for a particular investigation. The Geological Survey Bureau has operated a research drilling program since 1971. The purposes of this program include hydrologic evaluations of aquifers, coal reserves assessment, stratigraphic studies, environmental assessments, geomorphic analyses, and archaeological site evaluations. Fundamental to all programs requiring subsurface investigation is the need to collect accurate and representative samples of geologic materials.

Most of the program's operations are accomplished by a two-man drilling crew who work under the direction of geological-staff project leaders. The drilling crew is responsible for the actual drilling as well as the collecting, labeling, and preserving of samples; for managing the logistics of drilling equipment and materials; and for maintaining all tools and equipment. The drilling equipment is designed to work in two basic sampling environments: unconsolidated materials (soils and various glacial deposits), and consolidated rock (limestone, sandstone, dolomite, and shale). For the softer deposits, a trailer-mounted, hydraulic-powered drill is used to rotate and advance auger flights to obtain samples. If undisturbed samples are required, sampling tubes are hydraulically advanced to obtain continuous 4-foot cores. A series of such cores can be extracted if thicker intervals are of interest.

In the case of deeper drilling and drilling in bedrock, a conventional rotary rig is used. In this type of drilling, a rock bit is advanced at the end of a string of rotating drill pipe. Mechanical pressure on the pipe string maintains its downward advance. Water or a water-based drilling fluid is continuously circulated through the drill pipe to cool the bit and to force cuttings out of the hole. The cuttings are collected for each five feet of advance. These samples can be logged by experienced geologists, and the geologic sequence beneath the site defined. This equipment also has the capability of extracting solid rock cores. In this case, core tubes tipped by diamond bits are advanced into the rock, cutting solid core much in the fashion of a biscuit cutter. Solid cores are invaluable for providing details of in-place rock features that cannot be detected by studying well cuttings. Well cuttings can provide only representative materials through a 5-foot interval, while solid cores provide details within the vertical range of millimeters.

Although mineral resources investigations have been part of the research drilling program, water resources investigations have been its major emphasis. The latter uses the capabilities of research drilling to examine the geologic characteristics of Iowa's aquifers and their extents. Part of this process involves the development of wells to determine a variety of hydrologic parameters such as water levels, aquifer water pressure, direction of groundwater flow, impact of pumping, yield characteristics, and quality of water. These projects produce valuable information, applicable in many areas of the state's groundwater management, development, allocation, protection, and preservation. □



Paul VanDorpe

Research drilling enables accurate collection of soil, rock, and groundwater samples from specific geologic formations targeted for study.

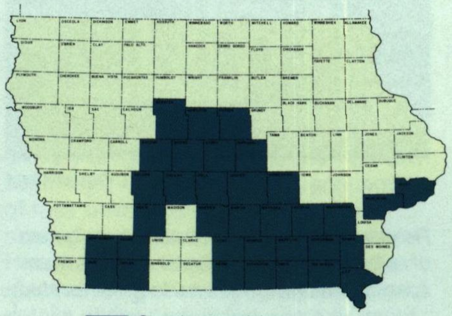
Paul VanDorpe

Extraction of solid, continuous cores are valuable for examining details of undisturbed geologic materials.

IOWA'S UNDERGROUND COAL MINES:

HISTORIC RECORDS COMPILED

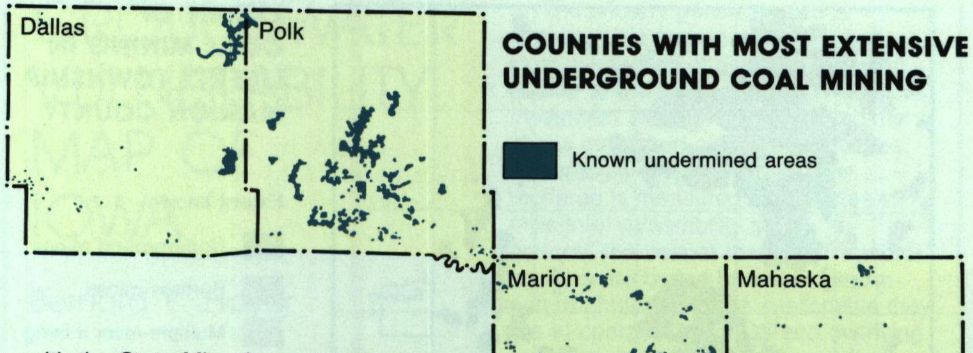
Mary R. Howes

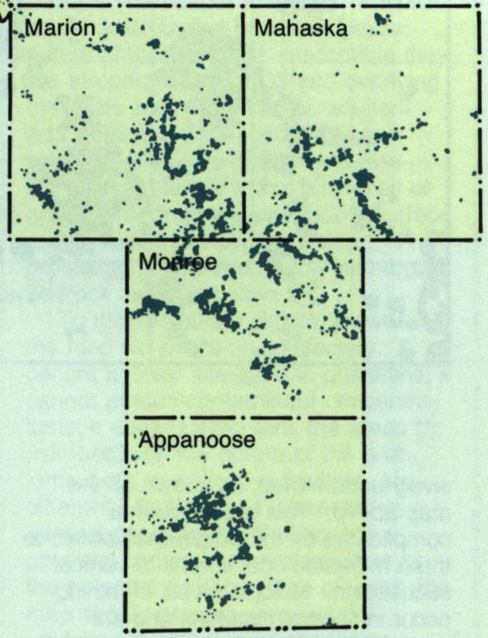


Counties containing underground coal mines

Coal has been mined by underground methods in 34 of Iowa's southern and central counties. This industry, nearly 150 years old, began in the 1840's with small drift mines dug into hillside outcroppings of coal and has evolved into a highly mechanized activity during the latter half of this century. Evidence of this past underground mining is usually subtle or nonexistent, in contrast to the disturbed terrain resulting from surface mining activity in the days before land reclamation was required. Thus, historic records kept at the time of mining are usually the only existing source of information for mine locations, the extent of underground excavations, and other characteristics. A thorough study of Iowa's available mining records has determined that approximately 5,500 underground mines have operated in the state. The records for each site vary greatly in accuracy and completeness. Mine locations and extents, information which is critical for evaluating the impact of underground mining on current or future land use, are vague or ambiguous in many of the records. Recently, coal mines were added to the Iowa Department of Natural Resources' Geographic Information System (GIS) by the Geological Survey Bureau. The Bureau's interpretation and compilation of these records for the GIS took into account their variabilities by organizing the results according to the accuracy with which the undermined area could be delineated on a map. In general, any mine that could be located within one square mile, regardless of whether its extent was known, was considered a mappable site and added to the GIS.

Slightly less than half (2,715) of the mine sites were determined to be mappable using the one-square-mile criteria. The extent of underground mining is known for 1,226 of these mappable sites. Of this latter group, over half (769) were documented by surveyed mine maps which included good locational references. These are considered the most accurately mapped mine sites. A few mines (80) were documented by surveyed maps, but had poor or ambiguous references to location. The remainder of the coal mines (377) had locations and extents documented by sources other than surveyed maps. The most common alternate sources were township maps prepared by the Office of State Mine Inspectors, followed by maps in the Iowa Geological Survey annual reports, and mining company lease maps. Comparisons of surveyed mine maps



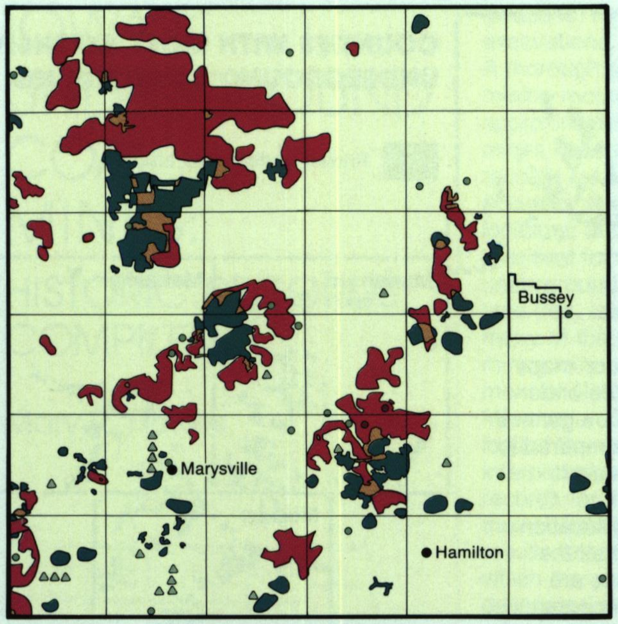


with the State Mine Inspectors' maps for the same sites showed the undermined areas on the latter to be generalized and usually enlarged compared to the areas shown on the surveyed maps.

The sites documented by location only (1,489) comprise over half the mappable mines. These sites are treated as point locations since the extent of underground mining is unknown. Information on a few of these mines suggests they were large producers of coal, probably undermining large areas; however, most of these mines were likely small local operations. The mines were classified by the precision with which they could be mapped, and two classes were established: 1) mines that could be located to within one quarter-section (835), and 2) mines that could be located to within one section (654).

Locations for approximately 2,800 other mines were too vague or too generalized to be useful. The exact number of these mines is difficult to determine because the records usually consist only of a mine name, a post office address, and a supervisor's name. It was difficult to determine if slight variations in mine names or supervisors' names indicated different sites or merely differences in the way the information was recorded for a single site. In addition to enabling sites to be mapped, precise location data would have helped resolve many conflicts in the identities of mine sites.

The area of underground mines having known geographic extents totalled 71,900 acres or 112 square miles. The bulk of this undermined territory is concentrated in four southern and two central Iowa counties (see map above). These six counties contain 82.4 percent of the documented undermined area in Iowa and 74.6 percent of the mines with documented extents. Distribution of affected areas within these counties is uneven as well. For example, Liberty Township in southeastern Marion County is exten-



EXTENT OF COAL MINING IN LIBERTY TOWNSHIP MARION COUNTY

Extent known
- Underground mines
- Surface mines
- Multiple-level mining

Extent unknown, location known within:
- 1/4 Section
- Section (square mile)

0 1 2 miles

sively undermined, as shown on the map above. This area is further complicated by the occurrence of two to three mineable coal seams in vertical succession. Multiple levels of mining occur in several locations and are particularly common where a surface mine overlies an underground mine. Although the largest total acreage of undermined land is in Monroe County, where over six percent of the county is affected (15,631 acres), most of the mined area in Polk County (14,914 acres) underlies the city of Des Moines and surrounding communities.

Although the evidence of past underground mining is often difficult to detect, abandoned mines continue to impact the environment and the future in various ways. Undermining makes the land surface unstable. Subsidence (sinking or collapse) of the land surface has occurred over abandoned underground mines in Iowa, and this process can be expected to continue. The phenomenon has been particularly troublesome in urban areas where repairs to subsidence-damaged buildings can be difficult and expensive. In addition, acid drainage seeping from underground mines has adversely affected agricultural land downslope from mined sites, both by its toxic effects and by keeping the land too wet to cultivate. Underground mines which adjoin or underlie surface mines also have complicated strip-mine reclamation projects by making slopes and highwalls unstable and causing persistent drainage problems. Finally, any future development of coal resources in Iowa will be directly impacted by past mining which may have removed part of the targeted resource and may complicate the operation of new mines. □

GROUNDWATER VULNERABILITY MAP OF IOWA

Bernard E. Hoyer

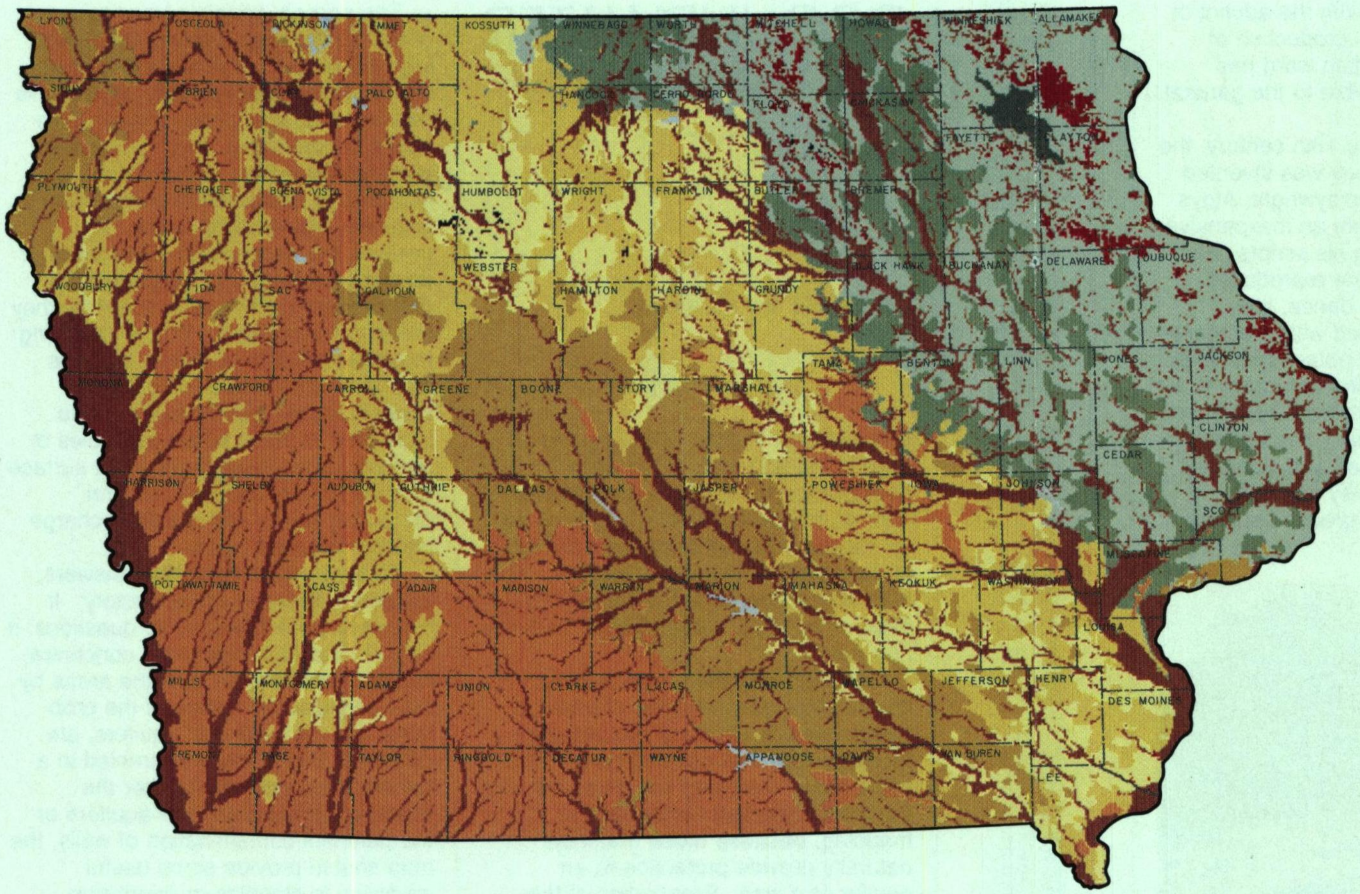
Groundwater Vulnerability Regions of Iowa is the first map of the state developed specifically to evaluate the intrinsic susceptibility of our groundwater resources to contamination by surface and near-surface sources. This map was prepared to fulfill a requirement of the 1987 Groundwater Protection Act.

The map identifies regions which have similar assemblages of physical characteristics affecting groundwater recharge and well development. The thickness of overlying soil materials was the most important factor used in mapping, because these materials naturally provide protection to an aquifer or a well. Preparation of the map also took into consideration the various types of aquifers, natural water quality in aquifers, patterns of well completions, and documented occurrences of well contamination. Geological patterns provided the basis for extrapolating the mapped patterns of potential contamination. The map is based on an unprecedented evaluation of geologic data, on review of Iowa's considerable data bases of water contamination, including the State-Wide Rural Well-Water Survey, and on insights gained from important research into understanding contaminant recharge, transport, and distribution in the environment.

The primary principle used to construct the map involves the hydrologic connection of either a well or an aquifer to the land surface. Where this movement of water can occur in time spans measured as days to decades, vulnerability is high. Where this recharge is measured in centuries to millennia, vulnerability is low. In general, the deeper that either wells or aquifers are buried by clayey glacial drift or shales, the less susceptible they are to contamination. Where overlying materials are thin or sandy, aquifers and wells are more susceptible to contamination. Vulnerability is also increased in areas where sinkholes or agricultural drainage wells allow surface and tile waters to bypass natural protecting layers and rapidly recharge bedrock aquifers below.

To those desiring simple answers, the map will prove unsatisfactory. It cannot answer site-specific questions; it cannot predict contaminant concentrations; it doesn't even rank the areas by risk--because the nature of the problems, both to wells and aquifers, are different. But to those interested in a general assessment of either the potential contamination of aquifers or the potential contamination of wells, the map should provide some useful guidance in planning or prioritizing activities.

Construction of the map required development or updating of several important primary types of geologic information. A complete, statewide revision of bedrock topographic mapping was done to improve upon maps made in the 1960's and 1970's. From this, the first depth-to-bedrock map of Iowa was produced. The project also generated another first: a statewide alluvial aquifer map. These separate mapping efforts are not published, but each is based on a complete review of all available well-log data, topographic maps, outcrop records, and soil survey reports so that



WATER SOURCE	CONTAMINATION POTENTIAL aquifers	wells
ALLUVIAL AQUIFERS	high	high
GOOD BEDROCK AQUIFERS protected by:		
Thin drift	high	high
Moderate drift	low	low
Shale	moderate	moderate
VARIABLE BEDROCK AQUIFERS Protected by:		
Thin drift	moderate to high	moderate to high
Moderate drift	low	low: bedrock wells high: drift wells
Shale	low	moderate: bedrock wells high: drift wells
DRIFT GROUNDWATER SOURCE	low	high
special features:		
SINKHOLES	enhance transport of contaminants	
AG-DRAINAGE WELLS	enhance transport of contaminants	
LAKES / RESERVOIRS		

GROUNDWATER VULNERABILITY REGIONS OF IOWA

confidence in the groundwater vulnerability regions map would be assured.

For the Geological Survey Bureau, construction of the vulnerability map (shown above as a simplified version of the actual 1:500,000 scale map) also represented a technological first. All of the mapping was prepared using computerized geographic-information-system technology, as part of a major Department of Natural Resources effort to integrate various types of natural resource data. This effort will allow disparate types of data to be brought together more effectively for analysis, and has the potential for enhancing decision making through the consistent utilization of all relevant factors.

While much was done to produce this map, much remains undone. Obviously, the unpublished maps which were developed during preparation of the vulnerability map need to be printed. But beyond that, in the course of conducting the research for this map, it became apparent that two important groundwater sources could not be mapped at all: buried channel aquifers (ancient Pleistocene valleys buried beneath glacial drift), and the even older (Miocene or Pliocene age) "salt and pepper sands" of western Iowa (see pages 22 to 24). Research into the distribution of these aquifers is essential to helping Iowans utilize groundwater resources, as well as to better assess areas where groundwater is vulnerable. Thus it is apparent that while this map is a first, it must not be the last. □

LITHOGRAPH CITY

Bill J. Bunker

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

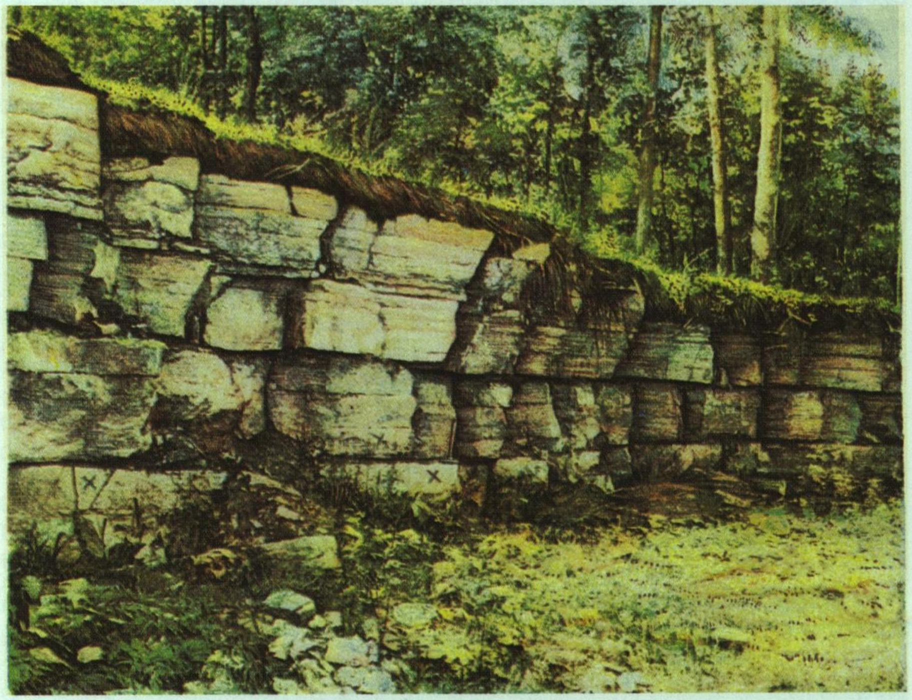
Near the end of the 18th century, the technique of lithography was invented by a young Bavarian playwright, Aloys Senefelder, who sought an inexpensive means of reproducing his scripts. He found that text could be reproduced from smooth slabs of dense, fine-grained limestone inked with a preparation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

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

At the turn of the 20th century, a town in north-central Iowa was founded because of this interest in high-quality lithographic stone. Sedimentary rocks in this part of Iowa include compact, laminated, lithographic limestones which were deposited during Devonian time (about 370 million years ago) as limey muds in shallow tidal-flat environments associated with cycles of worldwide lowering of sea level. These limestones are exposed along the Cedar River valley near the Floyd-Mitchell county line, and in 1914 they prompted Clement Webster, an enterprising citizen of Marble Rock, to establish a settlement called Lithograph City. Here the limestone was quarried and marketed to compete with the more expensive, imported Bavarian stone.

In the 1903 Annual Report of the

Lewis Quarry, southwest of Osage, Mitchell County, Iowa.
x x *Beds of fine grained lithographic stone.*



Gable Quarry, southwest of Osage, Mitchell County, Iowa.
x x *Beds of fine grained lithographic stone.*

Above: *Men with pry bars and horse-drawn skids for hauling stone work the layers of lithographic limestone at Quarry No. 1 in Lithograph City near the Floyd-Mitchell county line about 1914.*
Below: *Rough slabs of quarried lithographic stone sit outside the cutting plant where they are to be shaped and sanded before shipment for use in lithograph printing. (From Webster, 1915)*

Iowa Geological Survey, Samuel Calvin noted that samples of Iowa's lithographic stone were submitted for testing to the lithographing house of A. B. Hoen & Company of Baltimore, Maryland. Hoen's "Discussion of the Requisite Qualities of Lithographic Limestone, with Report on Tests of the Lithographic Stone of Mitchell County, Iowa" was also published in this volume. This report includes a color plate (VIII) printed on a sample stone from Mitchell County (see pages 16 and 17).

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

The onset of World War I curtailed the importation of Bavarian stone, and the operation at Lithograph City was expanded to meet the anticipated demand for quality stone. By 1915, Webster's community consisted of 15 houses, a hotel, general store, blacksmith shop, lumber yard, stone crushing and polishing plant, dance hall, and museum. The quarries operated for only a short period, however, and the town failed to prosper as metal engraving replaced lithographic stone in providing good quality printing at lower cost. After 1915, the town's name was changed to Devonia. A post office was never established, so the town is rarely found on maps or listed with abandoned towns in Iowa. By 1938 it was reported to be completely plowed under.

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

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

INTERPRETING ANCIENT CLIMATES IN IOWA

Greg A. Ludvigson
E. Arthur Bettis III

Concern has been expressed about possible effects of human activities on global climate. This concern has focused the attention of earth scientists on gaining a better understanding of glacial-interglacial climatic cycles during the last two million years (Quaternary Period). Of particular interest has been the transition from the last period of maximum glacial cold, 16,500 years ago, to the present. As these natural climatic shifts were of magnitudes similar to those postulated from unchecked human release of atmospheric greenhouse gases, measurement of these ancient variations in temperature and rainfall could more accurately assess the likely impacts of global climatic change on human affairs.

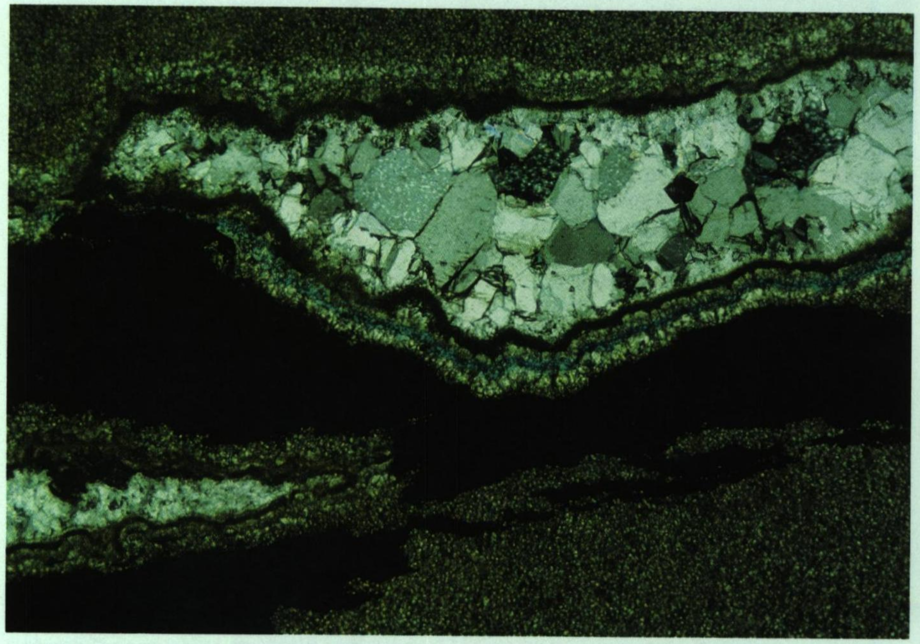
The use of stable isotopes as environmental tracers in Quaternary deposits offers a new approach to interpreting glacial and interglacial continental climatic cycles. These isotopes do not decay by nuclear fission; thus elements bonded in chemically inert, solid compounds have isotopic compositions that are fixed over geologic time. Additionally, many of the Earth's most abundant rock-forming elements have more than one common isotope, and the proportions of these isotopes vary between different earth materials. Differences in the isotopic ratios of common rock-forming elements, such as oxygen, result from physical and chemical reactions that cause the preferential concentration of one isotope over another. These controls include evaporation, condensation, and the temperatures at which minerals are crystallized in groundwater environments. Changes in oxygen isotopic compositions of sedimentary deposits are used as records of changing environments at the Earth's surface. Measuring the oxygen isotopic ratios of continental deposits can assist earth scientists in interpreting ancient rainfall and temperature regimes.

Calcium carbonate is a mineral that commonly forms at the Earth's surface, both by weathering processes and by the biotic precipitation of shells. Its abundance in sedimentary strata makes calcium carbonate an especially valuable paleoenvironmental indicator. Variations in the stable isotopic ratios of both oxygen (oxygen-18 to oxygen-16) and carbon (carbon-13 to carbon-12) in carbonate minerals each yield important but different types of information on environments of deposition.

Carbon isotope ratios of carbonates that form in terrestrial environments reflect influences of organic matter on carbon dioxide in soil gases, and are controlled by the relative dominance of different vegetation types. As carbon is assimilated from atmospheric carbon dioxide during photosynthesis, carbon-12 is preferentially taken up. The extent of carbon-13 to carbon-12 depletion depends on the photosynthetic pathway used by the plant. Two major plant groups are important in this regard, the plants of humid habitats and those that live in warm, semi-arid environments. Carbon fixed by these different plant groups has distinctive carbon-13 to carbon-12 ratios, so that stratigraphic successions of terrestrial carbonates recording changes in carbon isotopic ratios imply changes in dominant vegetation types, that are in turn controlled by climate.

During the last few years, we have been studying oxygen and carbon isotopes in terrestrial carbonate concretions from Quaternary deposits in western Iowa. These lime nodules occur in different stratigraphic positions within the area, and each group of concretions is related to a specific time interval of landscape stability and soil formation during the last two million years. We have detected significant differences in the isotopic ratios of concretions from several of these Quaternary weathering zones. The most unusual of these come from muddy sediments associated with the "salt and pepper" sands of western Iowa, which were accumulating over two million years ago (see pages 22 to 24). Concretions from this horizon have isotopic ratios that are strongly depleted in oxygen-18 and carbon-13 relative to all the other horizons, and we believe they record a period of much warmer climate than those recorded in younger Quaternary intervals.

Today, stable isotope analysis is addressing an expanding variety of unanswered questions in geology. Further work is needed to more fully interpret the paleoclimatic record of the last two million years which resides in Iowa's Quaternary deposits. □



Greg Ludvigson

Microscopic view of vein-fillings in a carbonate nodule from the "salt and pepper" sand interval in Mills County. Dark areas are soil-formed manganese oxides. Banded crystal growths may reflect fluctuating water tables related to alternating wet and dry climates. Magnified 34.5x.

SALT AND PEPPER SANDS OF WESTERN IOWA

Brian J. Witzke

The modern Missouri River drains a vast area of the American West, with many of its tributaries having headwaters in the Rocky Mountains. The Missouri forms Iowa's western border with Nebraska, and its channel has repeatedly shifted course across the broad north-south valley, which exceeds 15 miles wide in places. Unravelling the geologic evolution of this major valley to its present location has become an important element in the assessment of groundwater resources in western Iowa.

Reconstructing the ancestry of the Missouri drainage system involves various lines of geologic evidence. To establish a relative time framework, geologists must investigate the relationships between the various glacial-age deposits that lie above bedrock as well as the evidence of erosional gaps separating them. In general, these deposits consist of a complex sequence of glacial drift left by advances of continental ice sheets from the north at least eight times between about 500,000 and 2.5 million years ago. In addition, rivers deposited large amounts of sand and gravel during melting of these various glaciers as well as during warmer interglacial episodes like today. These buried deposits of sand and gravel are of particular importance to parts of western Iowa as sources of groundwater.

The Geological Survey Bureau initiated a study of these various river deposits in western Iowa during the late 1980's in an effort to understand their distribution, composition, origin, and water-bearing characteristics. Two general types were described: 1) sediments derived from glaciers or glacial deposits to the north and northeast, and 2) sediments resembling those in the modern Missouri and Platte rivers of Nebraska. Included in this latter group are fine-grained sediments called "salt and pepper" sands by well drillers in western Iowa. These sands form a potentially significant source of groundwater across some upland areas where they are commonly buried beneath 50 to 300 feet of glacial deposits. Scattered within the white quartz-rich sand grains are dark "pepper" grains which are identified as fragments of volcanic glass. Such volcanic grains are common in many modern and ancient river deposits known to have been derived from Rocky Mountain sources and deposited in eastward-flowing rivers.

No Rocky Mountain sediments are presently being deposited anywhere in Iowa because the Missouri River flows southward along Iowa's western border forming a barrier to eastward sediment transport. In western Iowa, tributaries of the Missouri River flow southwestward and contain sediment derived from the erosion of indigenous materials in Iowa, particularly wind-blown silt (loess) and older glacial deposits. However, western-derived sediments, especially the "salt and pepper" sands, are known to exist across broad areas of western Iowa. These sediments provide evidence of earlier deposition across Iowa by an eastward-flowing

Greg Ludvigson

The "salt and pepper" sands exposed in a Mills County quarry show angled patterns of cross-bedding which reflect shifting current directions in an ancient river system with headwaters in the Rocky Mountains.

drainage system before the Missouri Valley existed in its present form and location. The modern Missouri River valley cuts across the complete sequence of glacial tills in western Iowa. This suggests that the formerly eastward-flowing drainage was diverted southward by successive glacial episodes and acquired its present position sometime after the last advance of glacial ice in the area about 500,000 years ago. The history of this older west-to-east drainage across Iowa has been difficult to determine, but some important clues exist.

The youngest of the western-derived sediments occur above the oldest glacial tills in western Iowa, suggesting deposition as recently as 1.2 million years ago. However, most "salt and pepper" sands occur beneath the full sequence of glacial deposits, suggesting that some, if not most, of these deposits pre-date glaciation in western Iowa (older than 2.5 million years). Comparisons with similar sediments in eastern Nebraska show the Iowa materials most closely resemble some deposits in Nebraska of early Pleistocene, Pliocene, and Miocene age (about 1.2 to 15 million years old). Of note is the close

This tooth from a Stegomastodon, a distinctly Pliocene-age member of the ancient elephants, came from gravels at Akron, in Plymouth County, and places the age of this western-derived alluvium at 1.6 to 4.0 million years old. (Length is 9 inches)

Tim Kemmis

similarity with Ogallala Group deposits in Nebraska. The Ogallala is famous not only as a major aquifer on the Great Plains, but also as a significant source of abundant fossil mammal bones of late Miocene age (5 to 15 million years ago). Bones of small three-toed horses and rhinoceros are especially noteworthy in the Ogallala rocks of Nebraska.

In Iowa, fossils from comparable sediments are scarce, primarily because most western-derived materials are deeply buried. Nevertheless, Miocene and Pliocene fossil mammal bones and teeth have been collected in western Iowa, including representatives of three-toed horses, rhinoceros, and a characteristic mastodon (*Stegomastodon*). Although the Miocene horse and rhinoceros bones occur as reworked material within glacial-derived sands and gravels, their presence indicates that Ogallala sediments apparently were being eroded in areas of western Iowa following the onset of glacial conditions. A likely source for these bones includes some of the "salt and pepper" sands still present across parts of western Iowa. If true, some of these sediments may be of Miocene age.

Preliminary studies have characterized some general geologic relationships of these western-derived, "salt and pepper" sands in Iowa and have shed some light on the historical development of the Missouri River drainage; however, many questions remain. The full sequence of glacial, inter-glacial, and pre-glacial events has not yet been deciphered, even though western Iowa arguably preserves the most complete record of glaciation on the continent. In addition, the potential of these various sedimentary deposits to serve as aquifers is poorly understood. The need for dependable groundwater supplies in western Iowa is acute,' and it is hoped that the Geological Survey's proposal for additional research and drilling in western Iowa will provide, if approved, more satisfactory answers to fundamental geologic and hydrogeologic questions in the area. □

IOWA PERSPECTIVE ON MIDWESTERN EARTHQUAKES

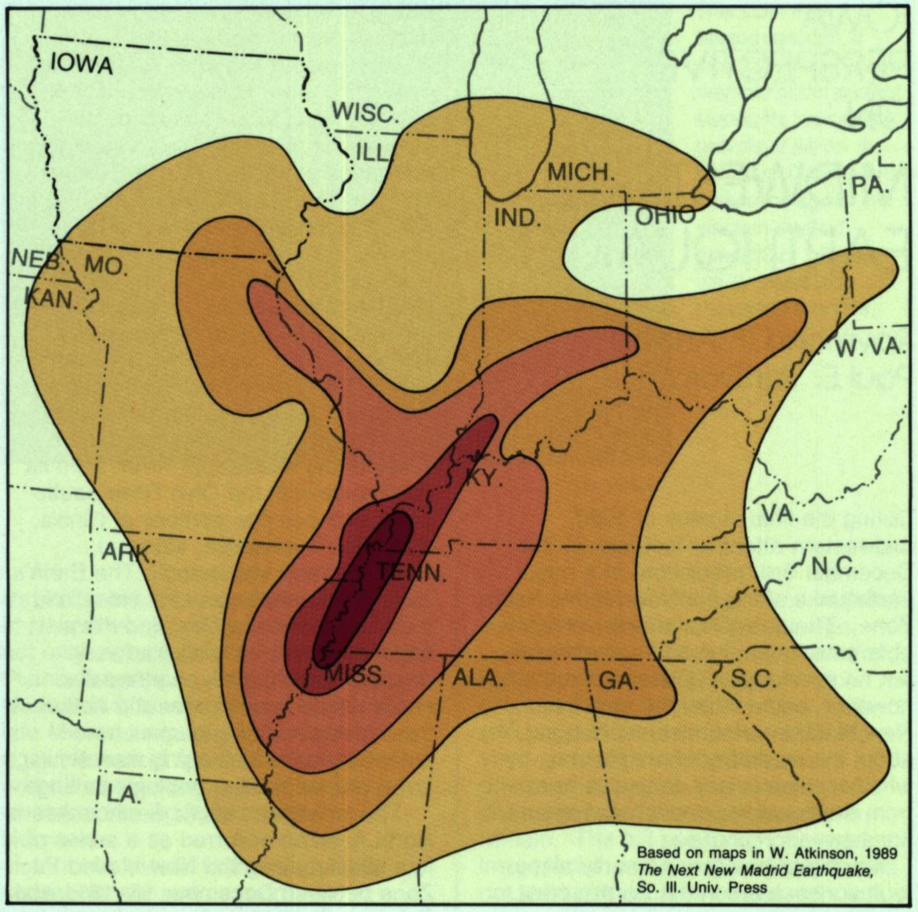
Raymond R. Anderson
Paul E. VanDorpe

During the final months of 1990, midwestern attention focused on the December 3rd "prediction" of a major earthquake along the New Madrid Fault Zone. The date passed with considerable public attention and some anxiety but no earthquake. Questions remain, however, about when the next major New Madrid earthquake could occur, about the credibility of predictions, whether there is any danger in Iowa from earthquakes, and what preparations are appropriate .

Earthquakes occur primarily along fault zones, tears in the Earth's crust, along which stresses build until one side of the fault slips, generating compressive and shear energy that produces the damage. Heaviest damage generally occurs nearest the epicenter, that point on the Earth's surface directly above the point of fault movement. The composition of geologic materials between these points is a major factor in transmitting the energy to buildings and other structures on the Earth's surface. Earthquake strength is recorded by a seismograph and is described using either the Richter Scale, which is a measure of the intensity of energy produced by an earthquake, or the Modified Mercalli Scale, which describes earthquake intensity by the damage that results.

While geologists often refer to the midwest as the "stable midcontinent," because of its lack of major crustal movements, there are two regions of active seismicity, the Nemaha Ridge and the New Madrid Fault Zone. The Nemaha Ridge in Kansas and Nebraska, associated with the Humboldt Fault, is characterized by numerous small earthquakes that release stresses before they build to dangerous levels. The area is not considered a threat to Iowa. The New Madrid Fault Zone, on the other hand, has a greater destructive potential. It is located along the valley of the Mississippi River, from its confluence with the Ohio River southward, and includes portions of Illinois, Kentucky, Tennessee, Missouri, Arkansas, and Mississippi. The Earth's crust in the midcontinent is older, and therefore thicker, cooler, and more brittle than that in California for example. Consequently, earthquake shock waves travel faster and farther in the midwest, making quakes here potentially more damaging than similar sized events in other geologic settings.

The strongest historic earthquakes in North America occurred as a series of four shocks along the New Madrid Fault Zone between December 16, 1811 and February 7, 1812 and were centered near the town of New Madrid, in the boot-heel area of Missouri. Based on historic eyewitness accounts, scientists have estimated the intensity of the earthquakes using the Modified Mercalli Scale and estimated an equivalent Richter magnitude of 8.3 to 8.7. These devastating earthquakes were felt from the Atlantic seaboard to the Rockies and felled trees, opened fissures, destroyed log buildings, erupted sand and water, created Reelfoot Lake in western Tennessee, and reportedly caused the Mississippi River to reverse flow in places. Because of the low population density, fatalities were



Based on maps in W. Atkinson, 1989
The Next New Madrid Earthquake,
So. Ill. Univ. Press

POTENTIAL AREAS AFFECTED BY A MAJOR* MIDWESTERN EARTHQUAKE along the New Madrid Fault Zone

*6.5 on Richter Scale

relatively few with most occurring on or near the Mississippi River.

Earthquake prediction is an inexact science. Even in areas that are well monitored with instruments, such as California's San Andreas Fault Zone, earthquakes are only rarely predicted by scientists. As in the case of the December 3rd prognostication, there are always people who will profess some special knowledge of natural events that transcends traditional science and who will attract media attention. The public will do well to look at the credentials of those who make such dramatic statements and to seek authoritative sources for dependable information.

Seismologists attempt to forecast earthquake size and frequency based on data from previous events. In the New Madrid Fault Zone, this analysis is difficult because there are few moderate to large earthquakes, and the active faults are too deeply buried to monitor effectively. Based on recurrence intervals for small earthquakes, scientists estimate a 40 to 63 percent chance of a Richter magnitude 6.0 earthquake between 1985 and 2000, rising to a 90 percent chance by 2040. Estimated recurrence intervals for larger earthquakes, approaching the size of the 1811-1812 events, vary from about 175 years to greater than 700 years. Will we get any warning prior to an earthquake? Maybe. Our understanding of earthquakes is increasing, and the future may bring a better forecasting system.

Estimated effects of a 6.5 Richter magnitude earthquake along the New Madrid Fault Zone (see map, left) suggest that Iowans in four southeast counties could experience trembling buildings, some broken dishes and cracked windows, movement and falling of small unstable objects, abrupt opening or closing of doors, and liquids spilling from open containers. About 29 other counties, from Page to Polk to Muscatine, could experience vibrations similar to the passing of a heavy truck, rattling of dishes and windows, creaking of walls, and swinging of suspended objects. These effects will vary considerably with differences in local geology and construction techniques.

The effects in the midwest of another severe earthquake like those of 1811-1812 would constitute a major disaster. The New Madrid Fault Zone is densely populated, with Memphis, Little Rock, Birmingham, Nashville, Louisville, and St. Louis all less than 250 miles from the most seismically active part of the area. In Iowa the direct physical effects would likely be minor to moderate, with structures built on poorly consolidated materials (such as river valley alluvium) nearest the epicenter suffering the heaviest damage. This could include fallen chimneys and cracked or broken walls and windows; disruption of local gas, water, sewer, and electric utilities; fluctuation of water levels in wells, springs, reservoirs, and streams; local landslides along steep slopes; liquefaction along floodplains; pressure changes in gas-storage facilities; and even land subsidence and sinkhole collapse. Additional consequences could include medical and other evacuations from damaged areas to facilities in Iowa, aid from Iowa sent to stricken areas, and increased east-west traffic through Iowa compensating for routes severed at the Mississippi River in the earthquake area.

Successful planning and mitigation efforts for earthquake events start with a knowledgeable public. Agencies such as the Federal Emergency Management Agency, the Central United States Earthquake Consortium, Iowa's Office of Disaster Services, and local emergency response teams are all concerned with providing aid in the event of natural disasters. Experts stress that most efforts to protect lives and property during earthquakes work equally well for any disaster, and these basic measures are usually not expensive and take little time to implement. Anyone can and should obtain information ranging from where to take cover during an earthquake, to upgrading home utility connections, and preparing an emergency survival kit. Midwesterners are well aware of how to protect themselves during tornados. How well we respond to an earthquake at home, at work, at school, or travelling will depend on how well we understand the risks and how well we prepare. □

SELECTED SURVEY PUBLICATIONS

NITRATE AND PESTICIDE DISTRIBUTION IN THE WEST FORK DES MOINES RIVER ALLUVIAL AQUIFER DNR-Geological Survey Bureau Technical Information Series 18, 43 pages, by C. A. Thompson (1990). Price $2.50, plus $.90 post./hand.

THE IOWA STATE-WIDE RURAL WATER-WELL SURVEY; WATER-QUALITY DATA: INITIAL ANALYSIS DNR-Geological Survey Bureau Technical Information Series 19, 142 pages, by B. C. Kross, G. R. Hallberg, D. R. Bruner, R. D. Libra, et. al. (1990). Price $2.50, plus $1.50 post./hand.

DEVELOPMENT OF A COAL RESOURCE DATABASE IN THE IOWA NATURAL RESOURCES GEOGRAPHIC INFORMATION SYSTEM FOR MONROE COUNTY, IOWA DNR Geological Survey Bureau Open-File Report 90-2, 70 pages, by M. R. Howes (1990). Price $3.50, plus $.90 post./hand.

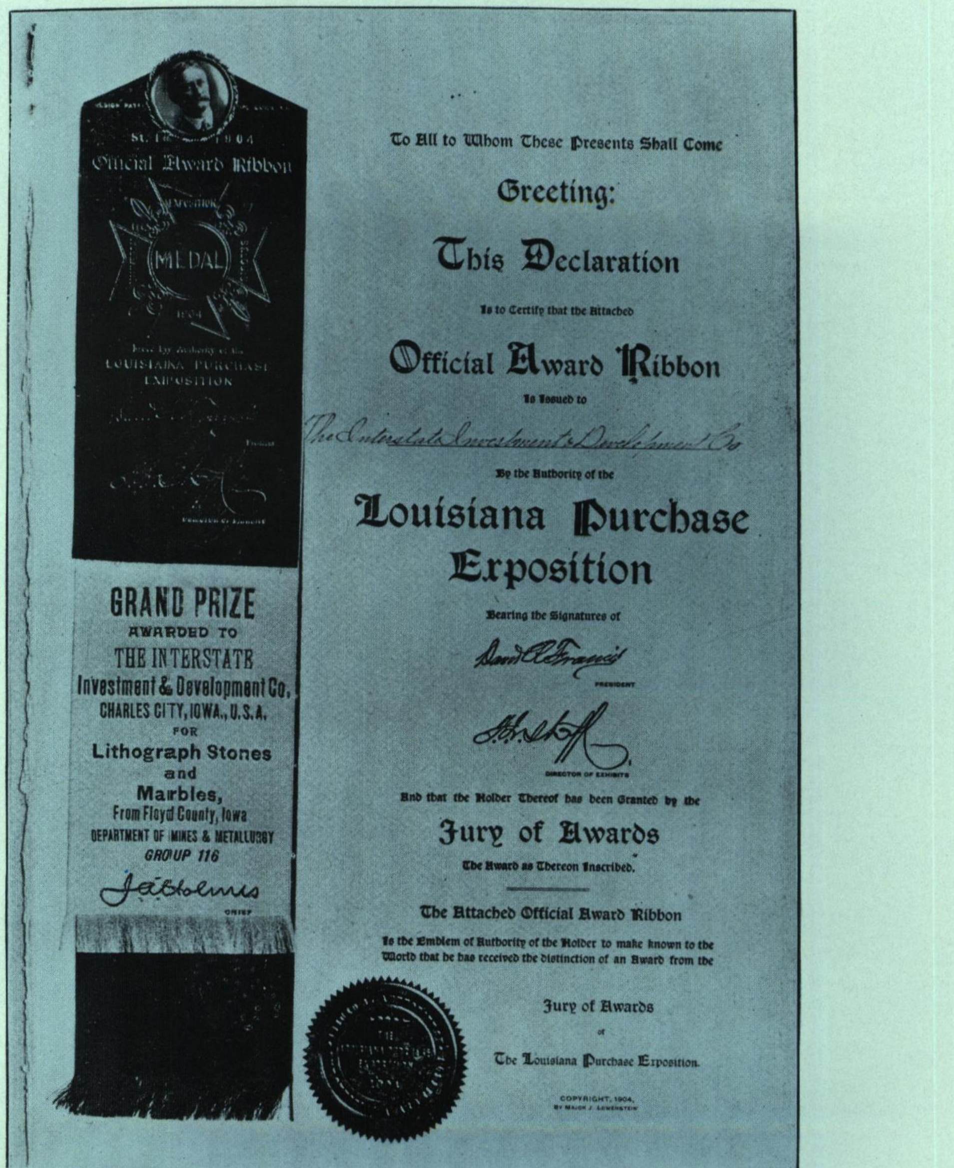
HYDROGEOLOGIC OBSERVATIONS FROM BEDROCK MONITORING WELL NESTS IN THE BIG SPRING BASIN DNR Geological Survey Bureau Open-File Report 90-1, 27 pages, by R. D. Rowden and R. D.Libra (1990). Price $1.50, plus $1.05 post./hand.

GROUNDWATER QUALITY OBSERVATIONS FROM THE BLUEGRASS WATERSHED, AUDUBON COUNTY, IOWA DNR Geological Survey Bureau Technical Information Series 20, 50 pages, by L. S. Seigley and G. R. Hallberg (1991). Price $2.00, plus $1.05 post./hand.

GROUNDWATER MONITORING IN THE BIG SPRING BASIN 1988-1989; A SUMMARY REVIEW DNR Geological Survey Bureau Technical Information Series 21, 29 pages, by R. D. Libra, G. R. Hallberg, J. P. Littke, B. K. Nations, D. J. Quade, and R. D. Rowden (1991). Price $2.00, plus $1.05 post./hand.

BIG SPRING BASIN WATER-QUALITY MONITORING PROGRAM: DESIGN AND IMPLEMENTATION DNR Geological Survey Bureau Open-File Report 91-1, 19 pages, by J. P. Littke and G. R. Hallberg (1991). Price $2.00, plus $1.05 post./hand.

GROUNDWATER VULNERABILITY REGIONS OF IOWA DNR Geological Survey Bureau Special Map Series 11 by B. E. Hoyer and G. R. Hallberg (1991). Price $5.00, plus $1.05 post./hand.



An international panel awarded the Grand Prize to samples of lithographic stone from Iowa during the Louisiana Purchase Exposition in St. Louis in 1904.