



**IOWA  
GEOLOGY  
1999**

**NUMBER 24**

# IOWA GEOLOGY

## 1999

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COVER: Variations in Iowa's land surface are shown in this remarkable map. Deep shadows, produced by computer enhancement, bring out the details of low-relief hills and valleys as well as intriguing broader patterns. Colors show ranges in elevation from lowest (blue) to highest (dark red).  
See map on pages 14-15.



**Iowa Department of Natural Resources**

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# IOWA'S STATEWIDE LAND COVER INVENTORY

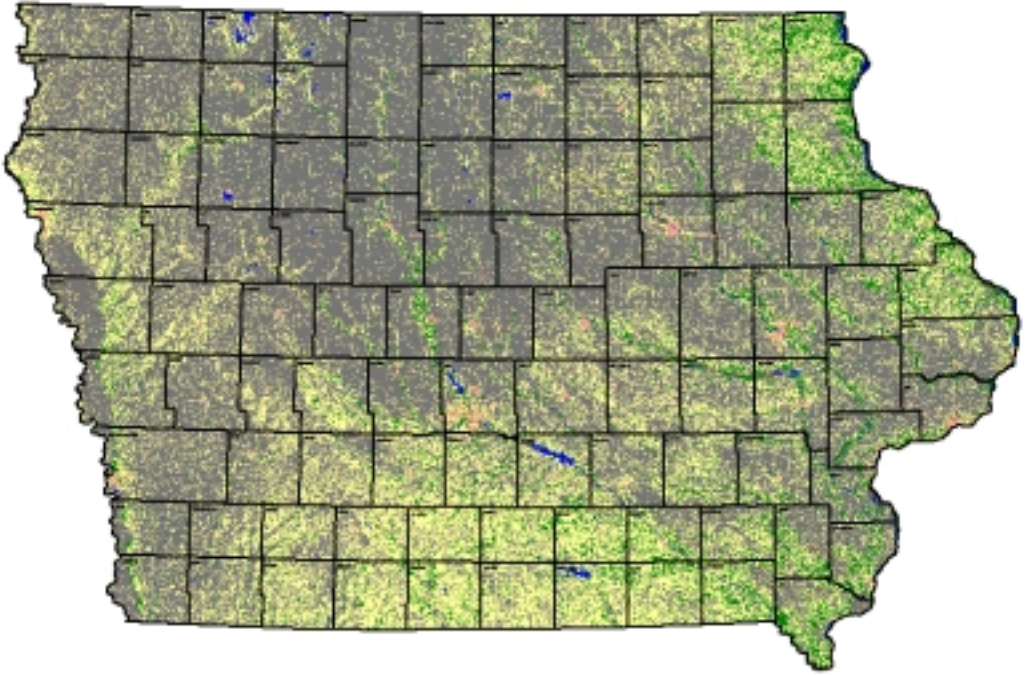
JAMES D. GIQLIERANO

The Geological Survey Bureau (GSB) has used aerial and space-borne imagery on a routine basis for the last 30 years. The discipline of imaging and measuring a subject without physical contact is called "remote sensing." Techniques for counting migrating geese, assessing flood damage, geological mapping, and determining land use and vegetative cover have been developed at GSB using this remote sensing technology. In the last 20 years these techniques have advanced beyond manual interpretation of photographs to computer-assisted processing of electronic imagery that allows enhancement of an image's appearance; the identification of patterns of vegetation, urban areas, and water; as well as the use of combined imagery from different sources. These new digital techniques do not replace the need for manual interpretation of images, rather they supplement GSB's ability to perform natural resource inventories and mapping.

Satellite imagery is particularly adaptable to conducting land cover

inventories over large areas of the earth's surface. The Thematic Mapper™ instrument on the current series of Landsat satellites can image a 185-square-kilometer area anywhere on the planet every 16 days. Once images are taken, the satellite sends them to a ground receiving station by radio transmission. Electronic versions of imagery are distributed to users for manipulation and analysis on their computers. Objects smaller than 30 meters are not resolved by the Thematic Mapper™ sensor, but patterns of fields, forest tracts, waterways, and large artificial structures are easily seen.

Several years ago, GSB began to map the major land cover types across Iowa as a baseline inventory for natural resource management programs of the Iowa Department of Natural Resources (DNR). Twenty-four Landsat satellite scenes were needed to cover the entire state, and many months of computer processing and image interpretation were required to complete the land cover inventory. A preliminary version of the completed mosaic for the entire state is shown on page 3. Most of the images are from 1992, but in some areas clouds dictated the use of imagery from 1990, 1991, or 1993. The land cover map shows that 60% of the state is covered by row crops; 30% by grasslands, including pasture, hay land, prairie, and wetland vegetation; and 7% by forest lands. Urban



## LAND COVER MAP of IOWA

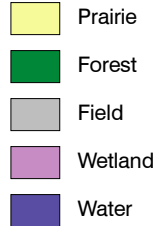
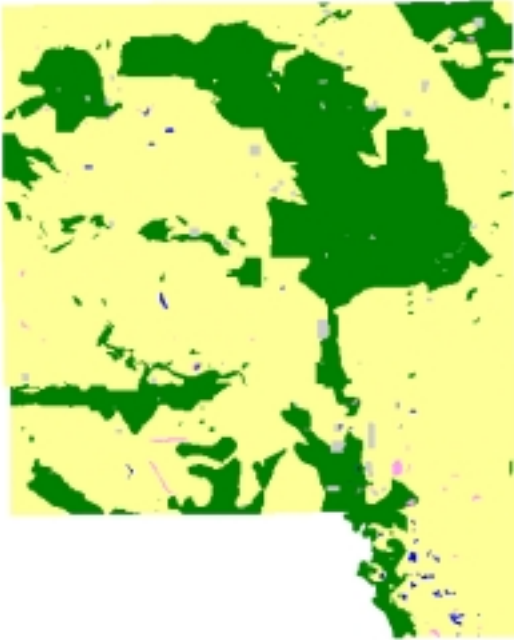


areas, including pavement, buildings, and other large structures, account for 1%, and water bodies cover another 1%. Too small to see on the map are barren areas (less than 1%) that include flooded cropland and sand bars.

While land cover and cropland acreage statistics are collected for each county on a routine basis, DNR's land cover inventory is unique in that it visually shows the

distribution of cover types across the state's entire landscape. The map clearly shows that most forest lands are concentrated in eastern Iowa along river corridors. Large areas of pasture and hay land are located in northeast Iowa, along with a broad, semi-circular swath in south-central Iowa. Rich cropland is particularly noticeable in north-central Iowa. Along the western border of the state, grass and trees mark the bound-

## VEGETATION MAP of JOHNSON COUNTY 1850s

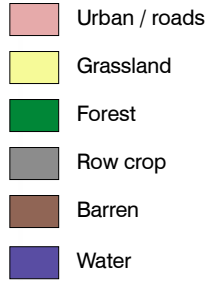
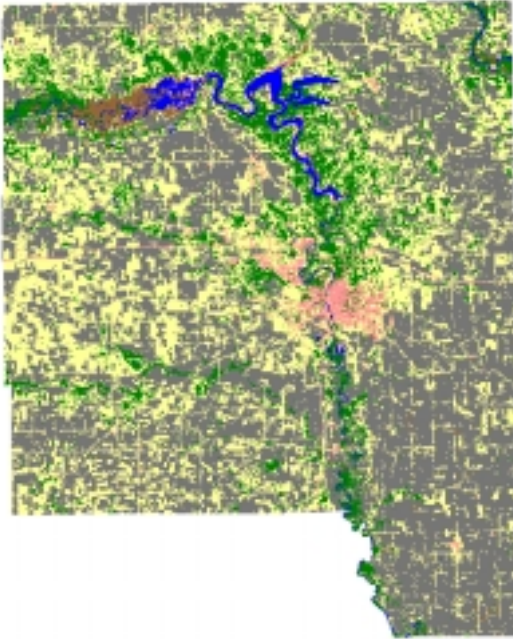


ary of the Loess Hills with the fertile Missouri River floodplain.

One of the most valuable uses of the land cover inventory is as a tool for evaluating changes through time. Recently, Iowa State University completed a series of county maps showing the distribution of pre-settlement vegetation taken from maps and notes of original Government Land Office surveyors in the mid-1850s. The map above shows this pre-settlement vegetation for Johnson County. Most of the county (70%) was covered with prairie vegetation, and included large tracts of

forest and oak savanna. A few small fields of crops are evident throughout the county. Compare this with the 1990s land cover information for Johnson County on page 5, taken from the statewide land cover inventory. Today, row crops cover 49% of the county, and very few prairie tracts remain. Almost all of the grassland represents residential lawns, parks, pasture, and hay fields. Seeing that most of the vast expanse of original prairie disappeared during the last 150 years makes one realize the importance of protecting the small remaining tracts.

## VEGETATION MAP of JOHNSON COUNTY 1990s



What will Iowa's landscape look like 10, 20, or 50 years from now? What patterns will be written on the land by agricultural market forces, government policies, technological progress, or perhaps human-induced climate change? Now, more than ever, there is a clear need for repeated assessments of Iowa's changing landscape. Future generations may look in wonder at the striking similarities or differences between their own landscape and that portrayed on this present inventory of Iowa's land cover.

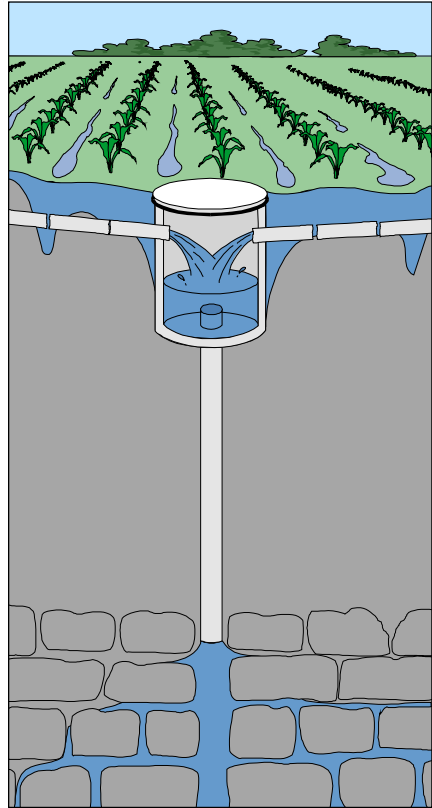
*The Thematic Mapper™ imagery for this inventory was made possible by the U.S. Geological Survey's GAP Analysis Project for Iowa, which is a detailed inventory of natural vegetation communities, land ownership, and the distribution of terrestrial vertebrate species. The Natural Resources Conservation Service collected information essential to "train" computer programs to identify the land cover types of every county, and to provide test data to assess the accuracy of the classification.*

# Closure of ADWs IMPROVES WATER QUALITY

LYNETTE S. SEIGLEY

Many of Iowa's rich agricultural soils, particularly those in north-central Iowa, are poorly drained and at times contain excess water that can interfere with field operations or even ruin crops. In these areas, farm fields are often artificially drained by buried tiles leading to drainage ditches or to streams. A less commonly used drainage method is the agricultural drainage well (ADW), a drilled shaft that funnels drainage water into the underlying bedrock (see illustration, right).

The upper parts of ADWs are often cistern-like structures that are the discharge points for one or more tile drainage lines; some wells are also designed to take surface runoff. ADWs are generally 5 to 10 inches in diameter and are cased into the underlying bedrock. Virtually all ADWs in Iowa discharge into fractured limestone aquifers, which can accept large quantities of drainage water without clogging. These aquifers are also excellent sources of groundwater for domestic, industrial, and



municipal water supplies.

An estimated 292 ADWs currently exist in Iowa, and nearly all were constructed between 1900 and 1950. From a statewide perspective, these wells are relatively uncommon. However, over 90% of the known ADWs in Iowa are concentrated in four counties: Floyd, Humboldt, Pocahontas, and Wright.

It has long been recognized that

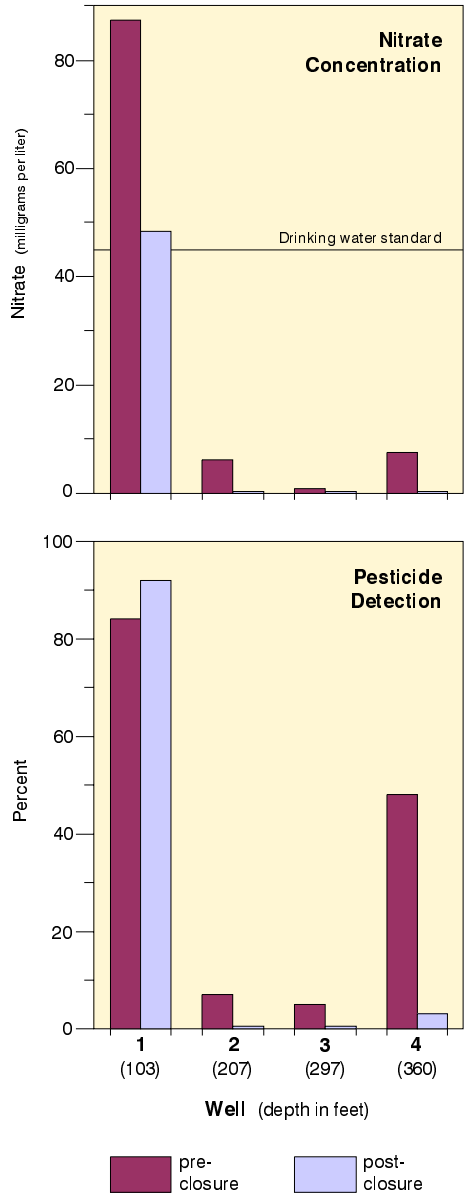


ADWs pose a threat to groundwater quality in Iowa, as they provide a direct route for delivery of contaminants such as nitrate, pesticides, bacteria, and sediment to the underlying bedrock aquifers. The impacts of ADWs are most noticeable after a rainfall, when surface water and tile drainage are delivered to the groundwater via the ADWs. During extended dry periods, drainage inputs are minimal, and ADW impacts are less severe.

Some ADWs are connected to drainage systems that accept water from road ditches. Spills or leaks of harmful substances into these ditches could quickly and directly impact groundwater supplies. A more recent concern is the placement of large-scale animal confinement facilities in close proximity to ADWs. The land application of manure from these facilities or a spill from a manure storage structure to a nearby ADW poses an additional threat to groundwater quality.

Past Geological Survey Bureau (GSB) groundwater-quality studies in Floyd County have shown that ADWs delivered agricultural contaminants, specifically nitrate and commonly used pesticides, into the Devonian-age limestone aquifers, otherwise protected by about 30 feet of glacial till (clay-rich sediment). Since 1984, GSB has monitored four bedrock wells (ranging in depth from 103 to 360 feet) near several ADWs in Floyd County. Results

## MONITORED WELLS



showed elevated nitrate concentrations and pesticide detections in the wells (see graphs, p. 7).

In 1994, the Floyd County Soil and Water Conservation District inventoried ADWs in the county. Owners of ADWs were asked about their willingness to close these wells and develop alternate surface outlets for the tile water. A total of 23 ADWs were voluntarily closed in Floyd County, including several that were more than 300 feet deep. In December 1994, three ADWs (two 65 feet deep; one over 300 feet deep) located within 3,000 feet of the four monitored bedrock wells mentioned above were closed, and tile water was diverted to a surface outlet.

Since closure of these ADWs, water quality has improved in all four bedrock wells. Nitrate concentrations have declined, and the number and concentration of pesticides detected also have declined (see graphs on page 7). Although the nitrate concentration in Well #1 has declined since the ADWs were closed, it remains slightly above the U.S. Environmental Protection Agency's established drinking water standard of 45 milligrams per liter (mg/L). The continued elevated nitrate concentrations and high frequency of pesticide detection indicate that this well also is impacted by contaminants entering the bedrock by a pathway other than the ADWs. Located within a few miles of this bedrock

well are areas where bedrock lies close to the land surface. These areas of shallow bedrock are very susceptible to contaminants entering the groundwater through infiltration and are likely contributing nitrate and pesticides to the aquifer in which the shallowest bedrock well (#1) is located.

Water quality has also improved in a nearby private well that serves as a source of drinking water. Prior to closure of the ADWs, nitrate concentrations in this well were greater than 65 mg/L. Since closure, concentrations are less than 20 mg/L.

Additional ADW closures will occur in Iowa, as a 1997 Iowa law requires that all ADWs located within a surface drainage area that includes a state-permitted earthen manure storage structure for an animal confinement facility must be closed by December 31, 1999 (later extended to December 31, 2001). Will closure of ADWs in other locations result in improved groundwater quality? Based on results from this monitoring project, the answer is probably yes.

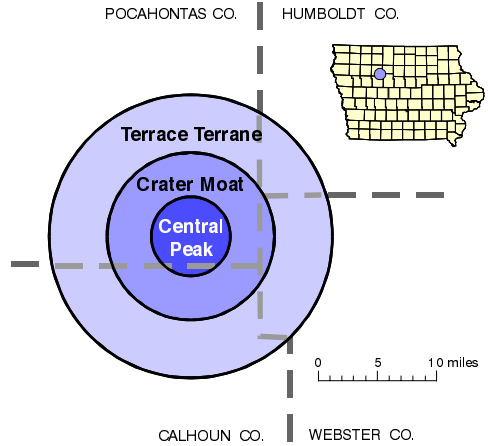
*This water-quality monitoring project was funded by the Iowa Department of Agriculture and Land Stewardship.*

# IOWA'S MANSON IMPACT STRUCTURE

RAYMOND R. ANDERSON

Seventy-four million years ago, near the end of the Cretaceous Period, central Iowa lay near the shoreline of an inland seaway that separated eastern North America from rapidly rising mountains to the west. The low-lying Iowa landscape was home to a rich and varied population of plants and animals, including dinosaurs and small mammals. These organisms lived in a fern-rich, mixed conifer and deciduous forest with a warm, moist climate much like today's Gulf Coast. The environment dramatically changed when a stony meteorite, over one mile in diameter, weighing about 10 billion tons and traveling about 45,000 miles per hour, blasted through the atmosphere and crashed to earth.

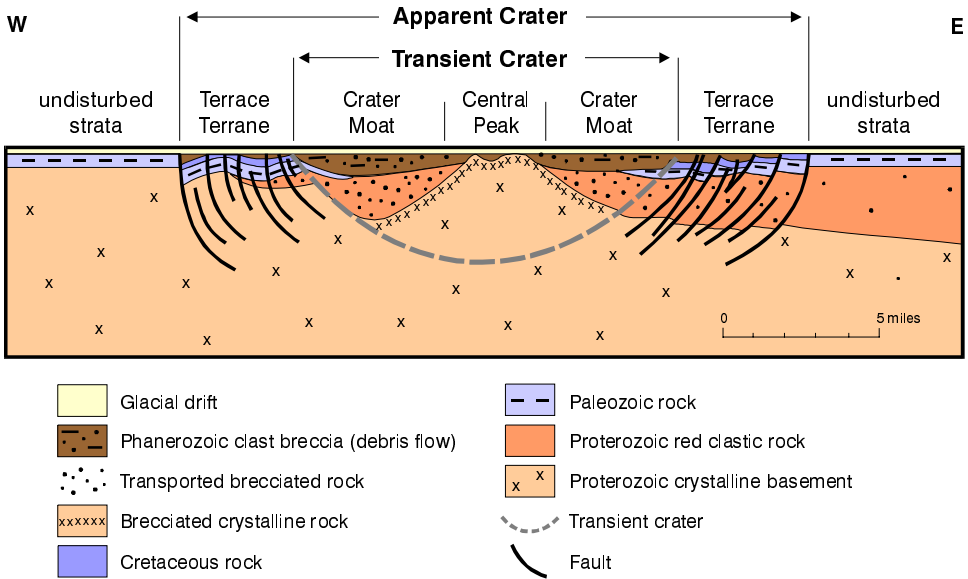
In the fraction of a second that it took the meteorite to penetrate about one mile into the ground, the shock wave created by the initial contact with the surface reached the back side of the meteorite and its potential energy was transformed to kinetic energy, the equivalent of about 10 trillion



*Location of Manson Impact Structure and principal features of its crater.*

tons of TNT. An electromagnetic pulse moved away from the point of impact at nearly the speed of light, instantly igniting anything that would burn within approximately 130 miles of the impact (most of Iowa). The shock wave toppled trees up to 300 miles away (Chicago, Minneapolis, St. Louis), and probably killed most animals within about 650 miles (Detroit, Denver). The blast left a crater over 24 miles in diameter centered in an area of unimaginable death and destruction.

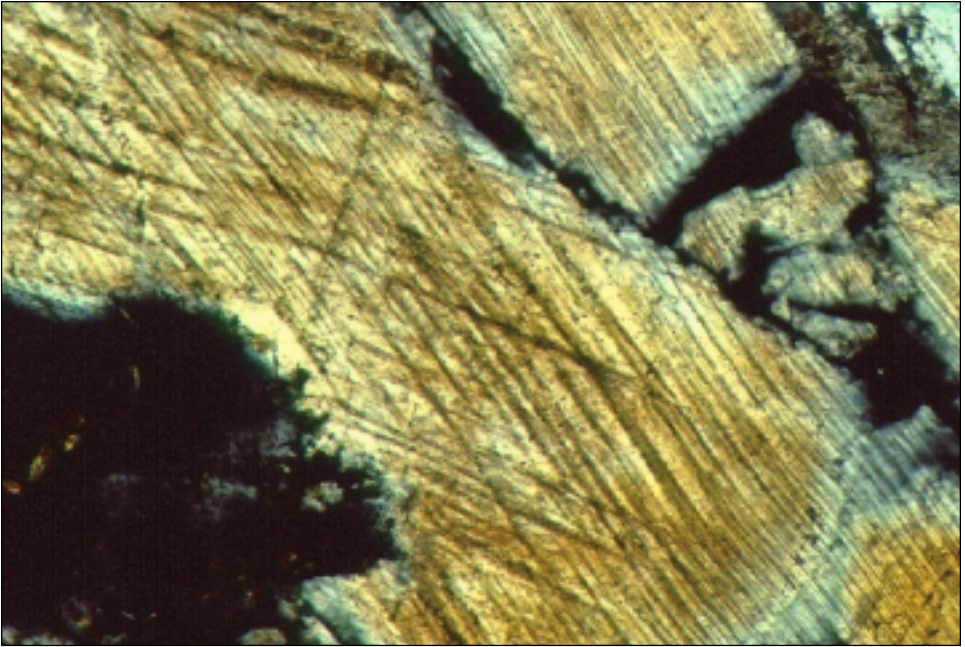
Today there is no land surface expression of the crater that exists 100 to 300 feet below the town of Manson (Calhoun County), which lies near the center of the crater that bears its name.



*Cross-section view of the geologic features of the Manson Impact Structure.*

The area of the Manson Impact Structure (see map, p. 9) has been known as a geologic anomaly since the early 1900s. At that time a new water well for the town of Manson encountered an unusual sequence of rocks that yielded the only naturally soft groundwater known in Iowa. The first investigation of the anomaly, in 1955, consisted of drilling two research cores and studying rock samples collected during water well drilling in the area. Since meteorite impact craters were almost unknown at that time, the feature was interpreted as a “cryovolcanic

structure,” a crater produced by a giant explosion of volcanic gases. The meteorite impact origin for the structure was first proposed by Robert Dietz in 1959 and confirmed in 1966 by Nicholas Short, who published photographs of “parallel deformation features” in quartz grains, including specimens from the Manson Structure. Short concluded that these features constituted incontrovertible evidence of a meteorite impact origin. The so-called “shocked quartz grains” (see p. 11) are produced when a high-energy shock wave generated by an impact passes through a



Ray Anderson

*A microscopic view through a thin-section of rock from the Manson Crater's Central Peak is shown. Lines in the brownish quartz grains are impact-derived "parallel deformation features." Such features are found at meteor impact sites around the world and are considered irrefutable evidence of extraterrestrial impacts. Horizontal field-of-view is 3 mm.*

quartz grain, creating thin regularly spaced zones of melting along preferred crystallographic planes. Extraterrestrial impacts are the only known natural force with sufficient energy to create these features.

In 1991 and 1992 the Geological Survey Bureau and U.S. Geological Survey began to investigate the possibility that the Manson impact played a role in the extinction of the dinosaurs and other

species at the end of the Cretaceous Period, 65 million years ago. During the course of this investigation 12 research cores, totaling over 4,000 feet, were obtained from all terranes of the crater. Study of those cores and other data by scientists throughout the United States and from several other countries produced a good understanding of the processes involved in the formation of the Manson Structure. This

investigation identified the Manson Structure as a “complex” impact crater; that is, it includes an outermost “Terrace Terrane” of down-dropped blocks, an inner “Central Peak,” and a “Crater Moat” in between (see diagram, p. 10).

Some of the most important data obtained from the research cores was a more accurate age for the impact, about 74 million years. Also significant was the identification of six types of impact rocks which were emplaced during actual crater formation. Four impact rock units were identified on the Central Peak. These include *Proterozoic Basement Blocks* (large blocks of granite and gneiss from below the crater floor); *Crystalline Clast Breccia with a Sandy Matrix* (smaller fragments of granite and gneiss in a matrix of sand-sized rock and mineral grains); *Crystalline Clast Breccia with a Melt Matrix* (similar to the previous unit, except most of the sandy matrix and many of the larger fragments have been melted); and the *Keeweenawan Clast Breccia* (broken and partially melted billion-year-old shale). The fifth impact rock type is *Ejecta* (rocks thrown from the crater during formation), found only in the Terrace Terrane. The sixth impact rock is *Phanerozoic Clast Breccia* (material originally stripped from the land surface, mixed with ejecta in a ground surge that moved ahead of the growing crater, and then quickly transported back into the crater by

returning sea waters). This material was found in all three terranes of the crater.

The shallow seaway retreated from the region of the Manson Structure within a few million years following the impact, exposing the area to erosion. Over the next 70 million years about 1,000 feet of rock layers were removed from the region by erosion, including all impact rocks beyond the crater. However, with its thick cover of Phanerozoic Clast Breccia for protection, only small areas on the Central Peak and Terrace Terrane were eroded. During the last 2.5 million years, continental glaciers covered the Manson area repeatedly. These glaciers further eroded the impact feature before blanketing it with glacial sediments that cover it from view today.

Although the Manson Impact Structure is now one of the best preserved and best studied complex impact craters on Earth, many unanswered questions remain about the effects of this impact on life forms. Additional developments in crater research as well as a detailed model of the crater's formation can be obtained from the Geological Survey Bureau's web site at [www.igsb.uiowa.edu/browse/manson/manson.htm](http://www.igsb.uiowa.edu/browse/manson/manson.htm).

# IOWA METEORITES

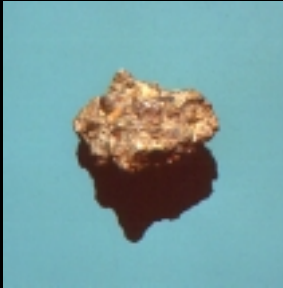
Historic accounts of meteorites striking Iowa make fascinating reading. They are but the latest of numerous asteroids that have bombarded the Earth throughout its history. This same process caused the impressive Manson Impact Structure in Pocahontas County (see p. 9).



On loan from Amana Heritage Museum

**Amana:** This 74-pound fragment was part of a dazzling fireball that fell near Homestead, in Iowa County, the wintery evening of February 12, 1875.

**Estherville:** A monument in Emmet County commemorates the exploding fall of a meteorite on May 10, 1879. This is one of three large fragments recovered.



On loan from Cornell College

**Marion:** Iowa's first recorded meteorite arrived with a loud blast heard throughout Johnson and Linn counties on February 25, 1847, the day the Legislature (then in Iowa City) established The University of Iowa.



On loan from The University of Iowa



On loan from Field Museum of Natural History

**Mapleton:** A slice sawed from a 108-pound iron meteorite found in June 1939, by a Monona County farmer shows the fine edges of large iron crystals.

**Forest City:** Rock fragments from this exploding meteor showered an eight-square mile area of Winnebago County on May 2, 1890.



On loan from Cornell College



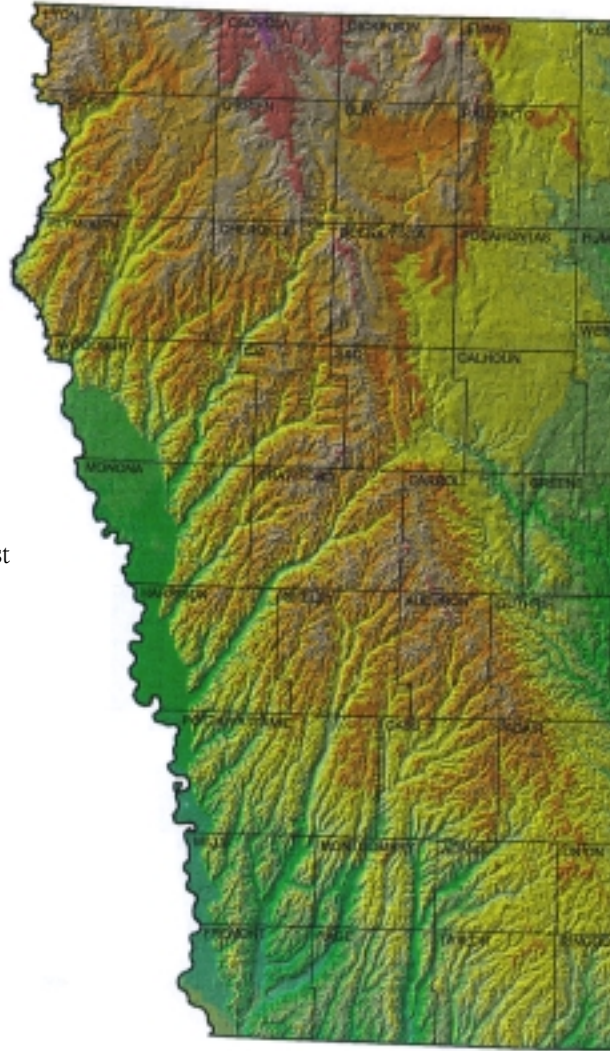
**Lone Tree:** This slab was sawed from a 46-pound stony meteorite discovered during cultivation in Johnson County in May 1972.

# SHADED RELIEF MAP of IOWA

JAMES D. GIGLIERANO

This striking view of Iowa's land surface is the product of a computer-generated model of elevations, illuminated by an artificial sun elevated 45 degrees above the northwest horizon, with colors applied to the elevation ranges. The lowest elevations are in blue, and the state's lowest point of 480 feet occurs where the Des Moines River enters the Mississippi in southern Lee County. Elevation increases with green, yellow, orange, and red colors. The highest elevation is in Osceola County in northwest Iowa at 1,670 feet. A prominent ridge curving from Osceola County south to Union County represents the drainage divide between the Missouri and Mississippi rivers. The relief revealed on this map depicts a landscape that was shaped by water, wind, and ice.

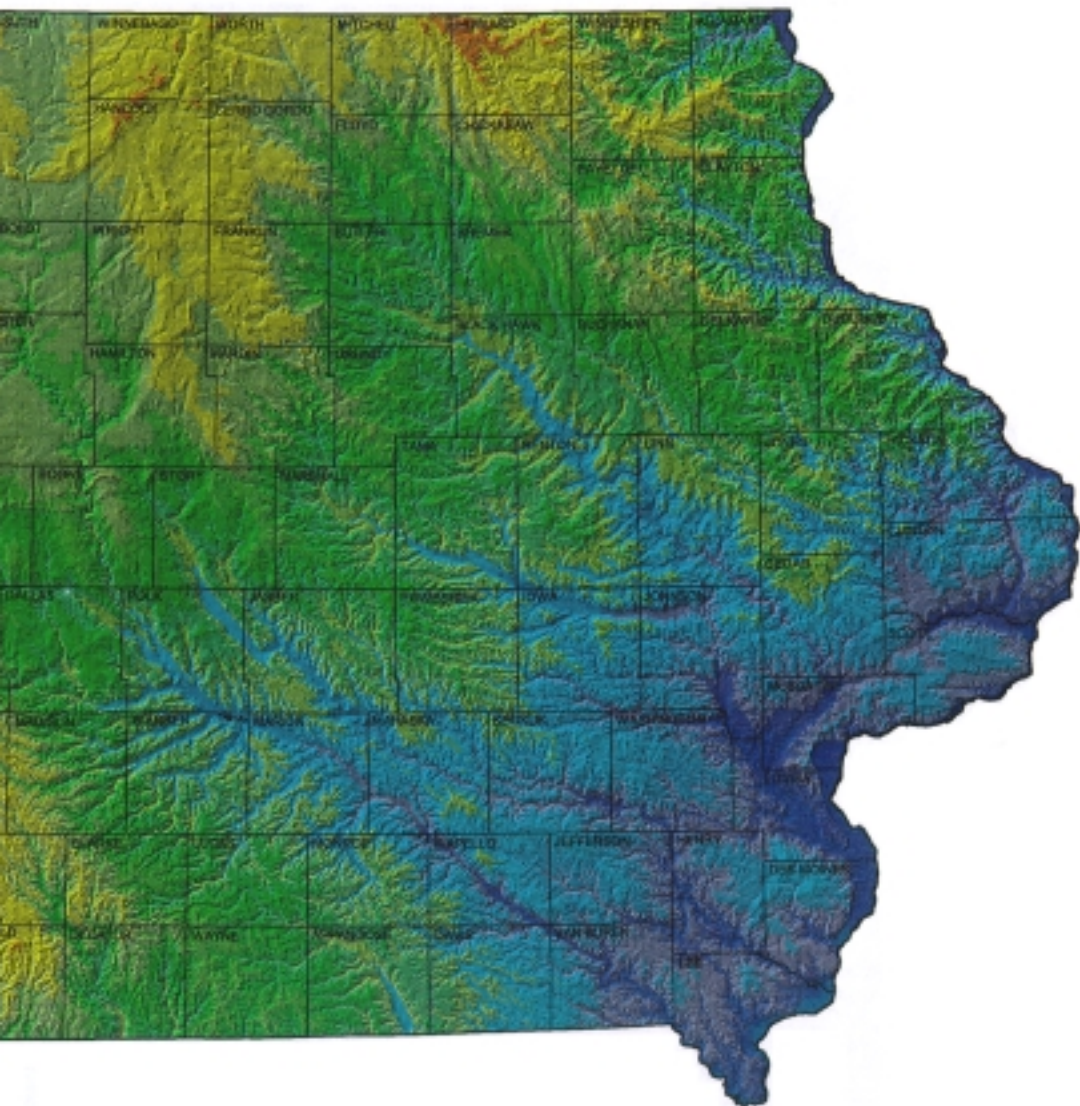
While this computer-generated, shaded-relief model may exaggerate the topography somewhat, it clearly shows that Iowa is far from being a flat, featureless plain. The map illustrates an intriguing variety of terrain features and elevations across our state.



**SURFACE ELEVATION ABOVE SEA LEVEL (APPROXIMATE)**







(APPROXIMATE)



# GEOLOGY OF WILDCAT DEN STATE PARK

**BRIAN J. WITZKE**

Wildcat Den State Park encompasses 417 acres along the Pine Creek drainage in Muscatine County, between Muscatine and Davenport. It is an area of exceptional beauty marked by imposing sandstone exposures. The park was formally dedicated in 1935 to preserve its scenic geology, diverse plant communities, archaeological resources, and historic sites. The restored Pine Creek Grist Mill, constructed in 1848, is one of the finest examples of a mid-nineteenth century grist mill to be seen anywhere in the country. A series of well maintained hiking trails affords the visitor easy access to many points of interest.

An array of geological resources in the park provides fascinating glimpses into Iowa's ancient past. The oldest bedrock, exposed along the margins of Pine Creek, includes about 25 feet of fossiliferous limestone and dolomite ("magnesian limestone") of the Cedar Valley Group. These rock layers formed from lime sediments that accumulated in shallow



Robert McKay

*A slot through the dramatic sandstone bluffs along Pine Creek valley takes visitors close to rocks that originated in a river channel 310 million years ago (Pennsylvanian).*

tropical seas that covered the region during the Devonian Period about 375 million years ago. The Devonian strata are best displayed below the dam next to the grist mill, where the beds are disrupted by small-scale faulting. Fossil corals, stromatoporoids (extinct sponge-like animals), fossil brachiopod shells, and skeletal pieces of crinoids ("sea lillies") are preserved in the bedrock along Pine Creek.

A considerable hiatus in the geologic



Robert McKay

*Stone used to construct the mill pond dam and a foundation for the 1848 Pine Creek Grist Mill came from the limestone outcropping seen to the right. These fossil-bearing strata were deposited in warm offshore seawater 375 million years ago (Devonian).*

record separates the Devonian strata from the overlying Pennsylvanian shale and sandstone units in the park. These Pennsylvanian strata reach thicknesses of about 100 feet and accumulated during the so-called “Age of Coal.” During this geologic period, eastern Iowa straddled the equator, and humid tropical forests stretched along ancient river courses and coastal lowlands that were present. Swamps accumulated masses of vegetation, later to become coal.

Salt-water estuaries encroached up the river valleys, as evidenced by brackish-water fossils and by sediments that reflected tidal rhythms. Deposits of gray shales and mudstones accumulated about 315 million years ago, yielding the soft rocks of the Caseyville Formation, which typically form overgrown soggy slopes along the lower valley walls of Pine Creek. The shales contain abundant organic material, and fossil ferns and “scale tree” foliage have



Robert McKay

*Rock overhangs and small sheltered caves result from weathering and erosion along zones within the sandstone that had different sedimentary histories.*

been identified within the park. Thin coal beds are also associated with this formation at Wildcat Den and in nearby areas of Muscatine County.

Picturesque sandstone cliffs and glens form the most noteworthy landscape features of Wildcat Den State Park. These sandstones belong to the Cherokee Group and were deposited about 310 million years ago (during Middle Pennsylvanian time),

subsequent to the underlying shales and mudstones. These strata contain the bulk of Iowa's coal resources, known especially from south-central Iowa. Springs and seeps occur at the contact between the porous Cherokee sandstone and the underlying, less permeable Caseyville shale (e.g., iron-rich springs near the base of Steamboat Rock) .

The sandstones were deposited in ancient river channels and record multiple episodes of erosion and deposition. Crossbedding of the quartz sand is prominent, and records the general southwesterly direction of flow within the rivers. In some places, iron-oxide cements form dramatic swirls and bands in the sandstones, and these are related to later chemical precipitation from mineralized groundwater. The delightful sandstone precipices and ravines spur our imaginations with a variety of images, reflected in part by the fanciful names that have been given to some of the prominent features, including Steamboat Rock, Devil's Lane, and Devil's Punchbowl.

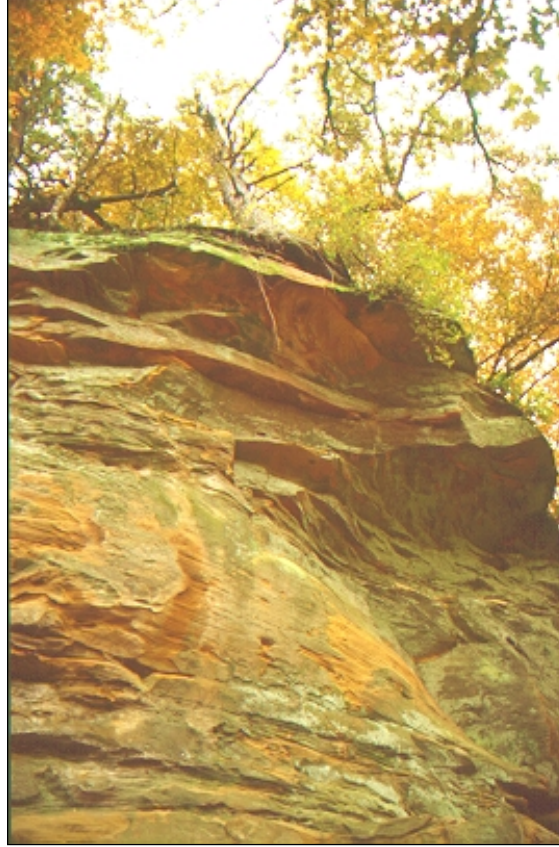
Later chapters of the geologic history of Wildcat Den State Park are interpreted from more recent sediments that mantle the bedrock. The area was overridden by continental glaciers several times during the Pleistocene "Ice Age." The most recent of these was the Illinoian glaciation which spread from Illinois into easternmost Iowa about 300,000 years ago, displacing the

ancestral Mississippi River channel westward into eastern Iowa. Remnants of these glacial sediments are scattered in the park's upland areas.

The most recent glacial advance (Wisconsinan) pushed southward across northern Iowa and areas of Wisconsin and Illinois, but did not reach into eastern Iowa. However, deposits of wind-blown silt (loess) did blanket much of the area and were derived from river valleys that carried huge volumes of sediment-laden glacial meltwater. Two silt units are recognized at Wildcat Den. The older Roxana Silt dates from about 55,000 to 28,000 years ago. The overlying Peoria Loess, which accumulated between 21,000 and 12,000 years ago, is typically about 20 feet thick in the uplands of the park.

Other important landscape changes occurred between 25,000 and 11,000 years ago, as eastern Iowa began to assume a more familiar form. Of special note, the channel of the Mississippi River shifted to its present location between Rock Island and Muscatine, and the modern stream drainage configuration began to develop.

The most recent aspects of the geologic evolution of Wildcat Den are found in the sediments, landforms, and cultural remains of the Holocene, the last 10,000 years. The advent of intensive agriculture and settlement in the area over the past 150 years have also modified the landscape and



Ray Anderson

*Iron is abundant in groundwater that moves through these cross-bedded sandstone outcrops. Rust-colored, iron-oxide stains and cemented zones are often seen on rock faces.*

stream courses.

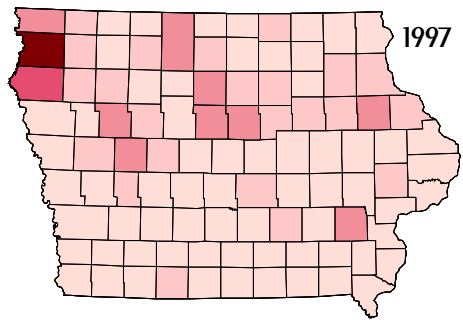
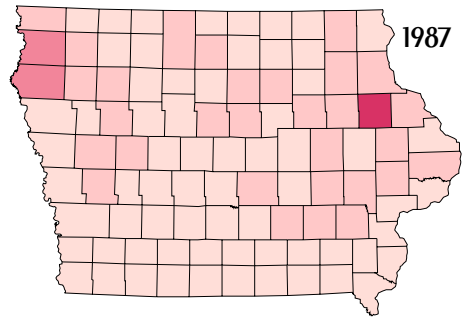
As we visit Wildcat Den State Park today, our experience is enriched by an appreciation of the history contained in the rocks, sediments, and landforms. Wildcat Den will serve as a clear reminder of our state's natural heritage for generations to come, a proud connection to this land we call Iowa.

# MANURE MANAGEMENT TO PROTECT WATER RESOURCES

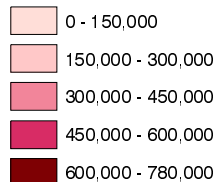
MATTHEW A. CULP  
AND GREG D. FUHRMANN

Methods of raising livestock in Iowa have changed dramatically in recent years. Today, increasing numbers of livestock are raised in concentrated populations within confined environments (see maps at right). These operations produce large volumes of manure that are temporarily stored in nearby earthen lagoons or basins (aerial image, far right) until applied to farmland as a nutrient source. As a result of this trend in livestock production, animal confinement operators are now required to submit a Manure Management Plan to the Iowa Department of Natural Resources (DNR) for approval. Each plan estimates the volume of manure generated at a particular facility, and proposes how and where the manure will be applied to agricultural land.

The concentrated populations of livestock, the large volumes of stored manure, and the application of manure to



**TOTAL HOGS IN IOWA  
(PER COUNTY)**



Source: Iowa State University Extension

farmland have increased concerns for safeguarding Iowa's water resources from the chemical nutrients and pathogens found in animal manure. These include nitrate, ammonia, and fecal bacteria.



(idealized photo image)

*Storage of manure in lagoons adjoining large, confined-animal feeding operations, and subsequent application of manure to the land, are environmental concerns in geologically vulnerable areas of the state.*

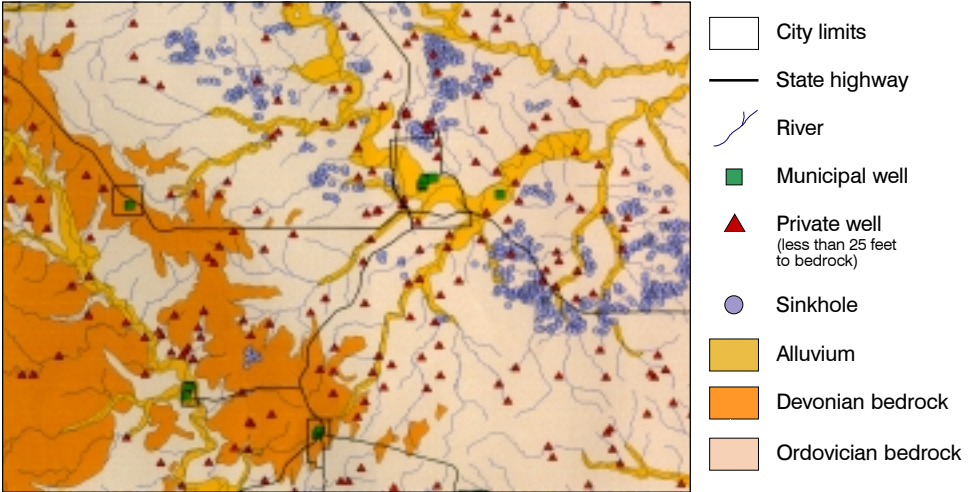
Environmental concerns involve the potential for excessive seepage of these contaminants from the lagoons and basins in geologically vulnerable areas. The same concerns apply to excessive concentrations of manure being applied to the land. Geologic vulnerability occurs where porous earth materials allow fluids and water-borne contaminants to move into an aquifer, potentially affecting private and public water wells in the area. Contaminants can also drain into a nearby stream or river. To address these potential contami-

nation problems, site assessments are conducted by DNR. Geologists review the known hydrologic and geologic conditions at each permitted manure storage structure, as well as the geologic deposits underlying the areas identified for manure application.

A vital tool used for these assessments is Geographic Information System (GIS) technology. State-of-the-art computer applications utilize a wide range of geologic and cultural data layered together in map form, which allows for comparison and analysis at any location. Bringing together

# GIS MAP OF THE DECORAH AREA (WINNESHIK COUNTY)

## USED TO EVALUATE GROUNDWATER PROTECTION



Horizontal map distance = 24 miles

accurate, up-to-date information from numerous data sources is an efficient and effective method for evaluating a site’s potential for groundwater contamination.

To actually conduct a site assessment for a proposed (or existing) manure storage structure, or for land designated for manure application, requires compiling the site’s GIS “coverages” on a computer screen. This is done by combining layers of data such as rivers, state highways, and urban area outlines. Information is initially compiled at a county-wide scale, and later the viewer can “zoom in” on the smaller geographic

area of interest.

Once common geographic reference features are compiled into a base map, other relevant data layers, such as sink-holes and public and private wells, are added until the final site coverage is constructed (see map above). Using this site coverage, an assessment can be made on groundwater vulnerability, and on whether other environmentally sensitive areas are located near the manure storage structure or the land application area in question.

Groundwater vulnerability is deter-



mined by several factors that can be evaluated using GIS technology. One important variable is the type and depth of groundwater aquifers that underlie a site. There are several types of aquifers in Iowa, and one or more could be present beneath a proposed manure storage structure or manure application area. Two of the most vulnerable geologic settings in Iowa are alluvial and shallow bedrock aquifers. Alluvial aquifers are composed of porous sand and gravel deposits that occur at or near the land's surface along streams and rivers. They are particularly vulnerable to seepage or spills from manure storage structures, or from land-applied manure because they have little if any natural protection.

Other aquifers that are particularly vulnerable are shallow bedrock aquifers, which are found in several counties in northeast Iowa and at scattered locations elsewhere in the state. These aquifers are composed of fractured limestone and dolomite, carbonate rocks that are subject to dissolution by infiltrating groundwater. Associated sinkholes and springs seen at the land surface are vivid expressions of their shallow, fractured, and easily infiltrated nature. Like alluvial aquifers, shallow bedrock aquifers have little or no protection from surface contaminant sources.

The vulnerability of Iowa's deeper

bedrock or buried alluvial aquifers is dependent on the type and thickness of glacial age materials that overlie them. These glacial materials may be sand, gravel, silt, or pebbly clay, and their horizontal and vertical distribution varies greatly across the state. Understanding the porosity and thickness of these materials is essential to assessing how well protected an underlying aquifer might be.

Another significant factor in evaluating a site involves the location, type, and depth of any nearby drinking water wells that tap a specific aquifer. Physical characteristics of these wells will determine the potential risk to human health posed by a proposed manure management site. Ecologically sensitive areas can also be identified on a site coverage. These may include communities of threatened, rare, or endangered plant or animal species, as well as state and county parks and preserves.

Based on the information found during the site assessment process, recommendations are made regarding needed modifications to the Manure Management Plan, the general suitability of a site for placement of a manure storage structure, or use of the land for manure application. This process is designed to protect Iowa's valuable water resources through the application of knowledge derived from on-going geologic research in the state.

# Global Climate Change and the Cretaceous Greenhouse World

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One of the most important earth science questions of our time is understanding how human activities may be modifying the current and future global climates. It is known that concentrations of heat-trapping gases or “greenhouse gases,” such as carbon dioxide ( $\text{CO}_2$ ), are increasing in the atmosphere. As more heat is trapped, global temperatures increase. Scientists have linked human activities such as burning of fossil fuels, forest clearing, and emissions from cars to the increase in heat-trapping gases. Carbon dioxide levels have increased from a pre-industrial concentration of 280 parts per million (ppm) to 360 ppm today, and  $\text{CO}_2$  levels continue to increase. There is wide scientific concern that the global climate system is already being affected. Noteworthy are the recent, rapid poleward retreats of sea-ice margins in the high polar latitudes, an especially sensitive part of the globe.

*Deep ocean basins (dark blue) and shallow inland seas (light blue) are shown in this view of the Earth 110 million years ago (Cretaceous Period). Note the opening of the central Atlantic Ocean caused by rifting between North America (upper left) and Africa (lower right). Image by Ron Blakey, Northern Arizona University.*

In January 1999, the American Geophysical Union (AGU) released a position statement on climate change and greenhouse gases that included the following passage: “The world may already be committed to some degree of human-caused climate change, and further buildup of greenhouse gas concentrations may be expected to cause further change. Some of these changes may be beneficial and others damaging for different parts of the world. AGU recommends the development and evaluation of strategies such as emissions

reduction, carbon sequestration, and adaptation to the impacts of climate change."

Future global greenhouse warming may be unavoidable. Atmospheric CO<sub>2</sub> concentrations exceeding 1,000 ppm could become a reality only a few centuries from now<sup>1</sup>. In order to plan for the impacts that accompany global climate change of this magnitude, an improved understanding of "Greenhouse Worlds" in the geologic past is needed. Elevated concentrations of CO<sub>2</sub> exceeding 1,000 ppm have not occurred during the last 1.65 million years, a period of time referred to as the "Ice Age" or Quaternary Period. The mid-Cretaceous Period (about 100 million years ago—during the "Age of Dinosaurs"), however, does represent a recent geologic analog in earth history that can be used to predict future greenhouse conditions.

The "Cretaceous Greenhouse World" refers to an episode of earth history that lasted from about 110 to 90 million years ago. During this time, submarine volcanic CO<sub>2</sub> emissions were released into the atmosphere at rates high enough to cause atmospheric CO<sub>2</sub> concentrations in excess of 1,000 ppm. This CO<sub>2</sub> buildup resulted from rapid sea-floor spreading related to the breakup and drifting apart of the Earth's continents<sup>2</sup>. The buildup lasted for about 10 million years, and the ensuing period of peak warming coincided with an explosive

growth in the genetic diversity of flowering plants, social insects, birds, and mammals—organisms that dominate modern terrestrial ecosystems. The consequences of a similar greenhouse buildup occurring over the course of only a few hundred years, however, are likely to be highly disruptive to natural ecosystems. Plants and animals live in zones of predictable temperature and precipitation. If this climate is altered too quickly, the species may not have sufficient time to migrate and adapt.

Recent paleoclimate modeling has provided insights into the nature of global warming during the Cretaceous. These results suggest that atmospheric CO<sub>2</sub> concentrations during the Cretaceous were four times current CO<sub>2</sub> levels, and the global mean temperature during the Cretaceous was 11.2°F warmer than present<sup>3</sup>. Some important questions remain about the amount and intensity of precipitation during the Cretaceous. It has been proposed that globally averaged precipitation in the Cretaceous Greenhouse World was 28% greater than present, although scientific data to verify this are only now being developed<sup>4</sup>. Ongoing studies of ancient terrestrial deposits on earth are needed to help scientists understand present trends and anticipate future global climate changes.

A team of research scientists at the Iowa Department of Natural Resources –

Geological Survey Bureau and the Department of Geoscience at The University of Iowa is leading an effort to explore relationships between temperatures and the stable oxygen isotopic composition of precipitation during the Cretaceous. Elements in nature consist of atoms with different masses called isotopes. The two most abundant oxygen isotopes are  $^{16}\text{O}$  and  $^{18}\text{O}$ . As water evaporates and condenses, the relative concentration of each oxygen isotope in water undergoes change. As atmospheric moisture is transported from the equator toward the North and South Poles, there is a progressive concentration of the lighter  $^{16}\text{O}$  in atmospheric moisture, as the heavier  $^{18}\text{O}$  falls as precipitation. Rainfall that occurs at different latitudes develops an isotopic "fingerprint" by which it can be identified.

This team of scientists is studying oxygen isotopic fingerprints of buried Cretaceous soils or paleosols that are currently being mined for brick manufacture by the Sioux City Brick Company in Sergeant Bluff, Iowa. These Cretaceous deposits are located at about the same latitude now as then. The paleosols contain a soil-formed mineral, sphaerosiderite ( $\text{FeCO}_3$ ), that had crystallized in water-saturated settings. The oxygen isotopic composition of these iron-carbonate minerals (see photo, p. 27) records temperature and precipitation conditions during the

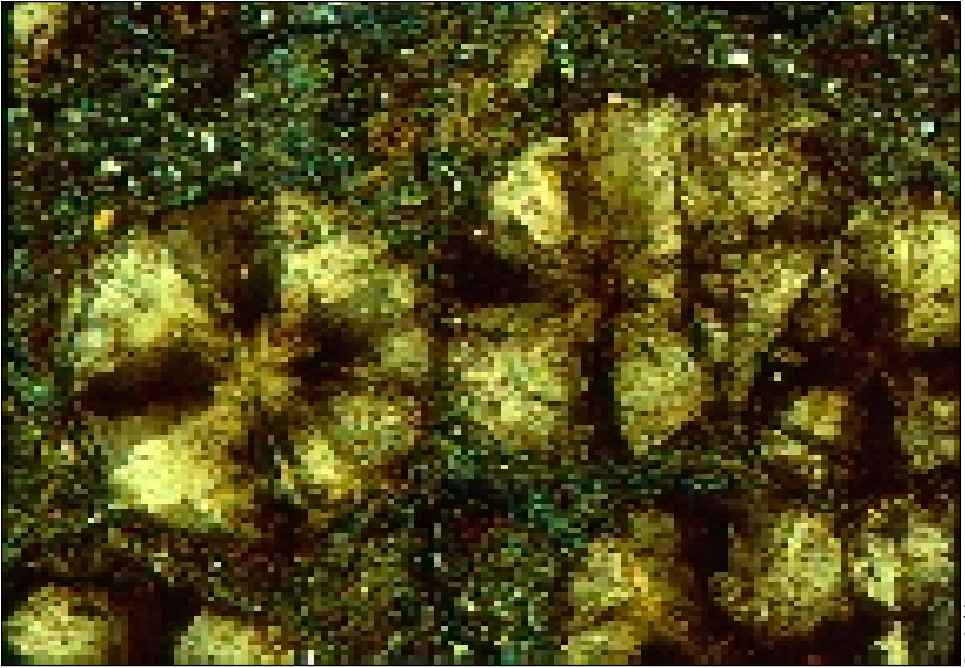
Cretaceous at the latitude where they formed <sup>5</sup>.

Studies of sphaerosiderites in Cretaceous paleosols of North America show dramatic evidence that atmospheric moisture transport and precipitation intensity during the Cretaceous Greenhouse World were very different from that of today. Cretaceous sphaerosiderites are considerably more depleted in the heavier  $^{18}\text{O}$  isotope for their respective paleolatitudes than the values calculated for those same latitudes today using modern meteorological data. This difference is generally interpreted as the result of significantly greater global rainfall during the Cretaceous Period.

A major goal of this research is to gather geological information from the field that can be used to refine models simulating ancient greenhouse episodes such as the Cretaceous Greenhouse World. The knowledge gained from these models can lead to more accurate and reliable forecasting of the impacts of future global greenhouse conditions.

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*This is a microscopic view through a thin slice of 100-million-year-old buried soil sampled from rocks mined at the Sioux City Brick Company in Sergeant Bluff. The spheres are nodules of the mineral sphaerosiderite, an iron carbonate that preserves records of ancient temperature and precipitation in its isotopes. (Cross-polarized light; horizontal field of view is 3.2 millimeters.)*

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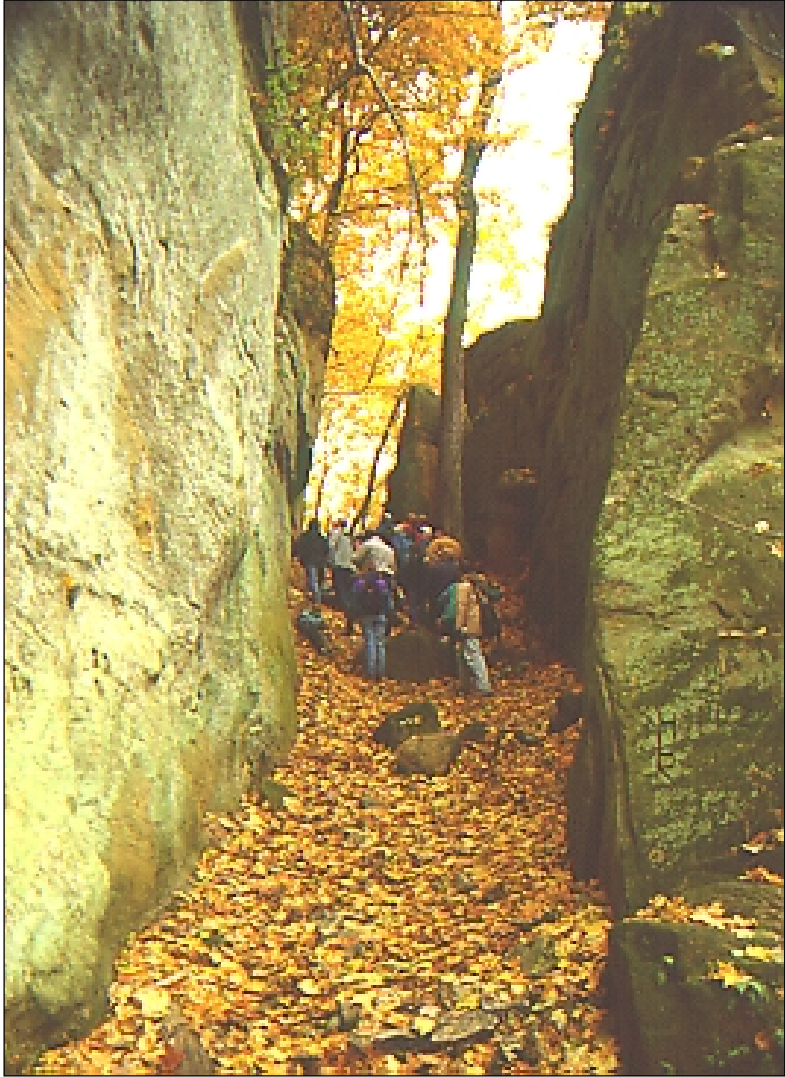
# CONNECTING WITH THE LAND

Over the course of many thousands of years, Iowa's land has evolved into watersheds, soil types, natural habitats, geologic deposits, and ground-water aquifers. We connect with these earth systems while hiking along rock outcrops, scanning the horizon from a tractor seat, admiring a roadside prairie, fishing from a stream bank, or drinking from a water fountain. Tuning into the deeper aspects of these systems, recognizing and understanding them, is essential to sustaining our future here. Since Iowa established its borders in the 1840s, this land has been divided into counties, sectioned with roads, fenced into farm fields, and platted into lot lines. These artificial boundaries tend to distance us from the earth systems that continue their natural rhythms around and beneath us.

Paul W. Johnson, newly appointed Director of Iowa's Department of Natural Resources, refers to Iowa's ground as "working land," an apt phrase that suggests our state's terrain is a "sleeves rolled up" sort of a place, focused on the job of nurturing green growth from a landscape of extraordinarily productive soils. And Iowa's people are widely dispersed across the land, interacting of necessity with nearly all of the state's terrain on a daily basis.

While Iowa's "working land" sustains us economically, we also need to experience and think about the land in different ways. The value of Iowa's land also includes the natural features that show us the rich diversity of our landscape prior to cultivation. A "value-added crop" harvested from Iowa's land can be the growth of a sense of familiarity, respect, and stewardship for its natural systems and their time-honored patterns and resources.

**JEAN CUTLER PRIOR**  
Editor



Ray Anderson

*Wildcat Den State Park*