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Iowa
Department of Natural Resources

COVER:

These translucent stones, tumbled to a high polish, are composed predominantly of varieties of quartz and include beautifully banded Lake Superior agates, which are prized by rock collectors.

Cover photo by Timothy J. Kemmis
Cover design by Patricia Lohmann

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

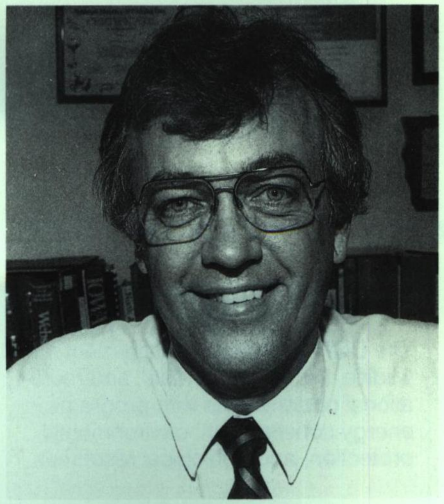
Editor's Note: The secretarial assistance of Mary Pat Heitman, the editorial assistance of John Schmidt, and the cooperation of the individual authors are appreciated.

CONTENTS

IOWA DEPARTMENT OF NATURAL RESOURCES:

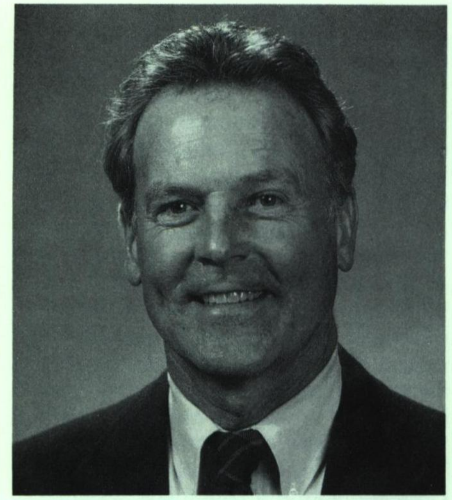
DEDICATED TO RESEARCH, INFORMATION, AND PUBLIC SERVICE

With the reorganization of state government in July 1986 came the consolidation of four separate agencies, each with responsibilities in the area of natural resources. The new Department of Natural Resources (DNR) merges the functions of the Iowa Conservation Commission, established in 1935; the Department of Water, Air, and Waste Management (1981); the Iowa Energy Policy Council (1974); and the Iowa Geological Survey, first established in 1855. The DNR is headed by the Director, who is appointed by the Governor. The eight divisions of the DNR include: Administrative Services; Coordination and Information; Energy and Geological Resources; Environmental Protection; Fish and Wildlife; Forests and Forestry; Parks, Recreation, and Preserves; and Waste Management Authority. A well-qualified staff dedicated to providing reliable information and assessments will help ensure that the DNR's mission of prudent protection, management, and use of Iowa's natural resources is accomplished. □



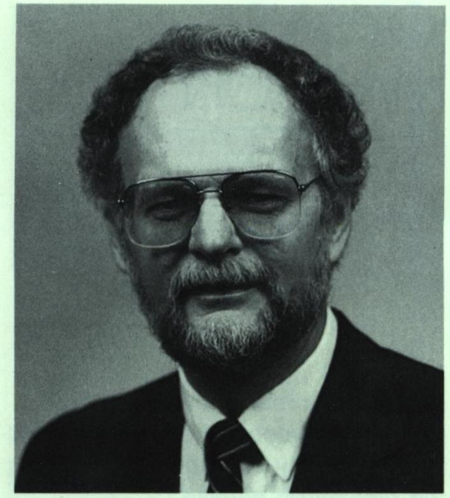
Larry J. Wilson
Director

Larry Wilson was named Director of the newly established Department of Natural Resources in July 1986. Prior to that appointment he served as Director of the Iowa Conservation Commission, beginning in 1981, and is noted for his commitment to the conservation and multiple use of a broad range of outdoor resources. A native of LeRoy, Illinois, Larry received his college education at Utah State University earning a B.S. degree in fisheries management. For 16 years prior to coming to Iowa, he worked for the Utah Division of Wildlife Resources as a regional fisheries manager and biologist, and later as southeast regional director for all agency operations. Larry is a member of the American Fisheries Society and The Wildlife Society and has held primary offices in the Kiwanis Club, Elks Lodge, and his church. He enjoys gardening, racquetball, hunting, fishing, bicycling, and reading history. □



Larry L. Bean
Division Administrator
Energy and Geological Resources

Larry Bean served as Senior Energy Management Executive of the Iowa Energy Policy Council from 1981 until the agency became part of the new DNR. His varied career includes experience as a power plant operator for Iowa Public Service in Sioux City, a member of the science faculty at Kirkwood Community College in Cedar Rapids, and president of his own company, directed toward commercialization of solar energy. Larry, an Iowa native, received a B.S. degree in biology/chemistry from Morningside College (Sioux City), an M.S. degree in zoology from the University of South Dakota, and was a National Science Foundation Fellow. His outdoor recreation interests include photography, camping, fishing, sailing, skiing, bird watching, and shade gardening. □



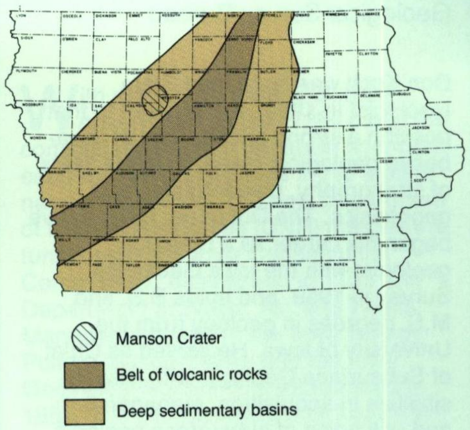
Donald L. Koch
State Geologist and Chief
Geological Survey Bureau

Don Koch was appointed State Geologist in 1980, and brought to that position a strong background of Iowa-based geological research in the fields of stratigraphy, paleontology, and geophysics. The Dubuque, Iowa, native began his career as a research geologist with the Iowa Geological Survey in 1959, and holds B.S. and M.S. degrees in geology from the University of Iowa. He served as Chief of Subsurface Geology, with responsibilities in acquisition, management, and utilization of subsurface geologic and hydrologic data, and in 1975 was appointed Assistant State Geologist. Don is an active member of the Association of American State Geologists, the Iowa Academy of Science, the Geological Society of Iowa, and the Iowa Groundwater Association. He enjoys bicycling, camping, chess, coin collecting, and delving into the history of geological investigations in Iowa. □

IOWA'S MANSON CRATER

Brian J. Witzke
Raymond R. Anderson

Apparently created by the impact of a large meteoroid or asteroid, its formation may have helped trigger the dinosaurs' demise.



One of the most unusual geologic structures known on the North American continent lies buried beneath 50 to 300 feet of glacial deposits in the productive farmlands of north-central Iowa. This pastoral landscape reveals no clues about an event that shook the area with unprecedented explosive force about 66 million years ago. The geologic structure, now known as the Manson Crater, is roughly circular in outline with a diameter of about 20 miles and is centered north of the town of Manson near the Calhoun-Pocahontas county line (see map).

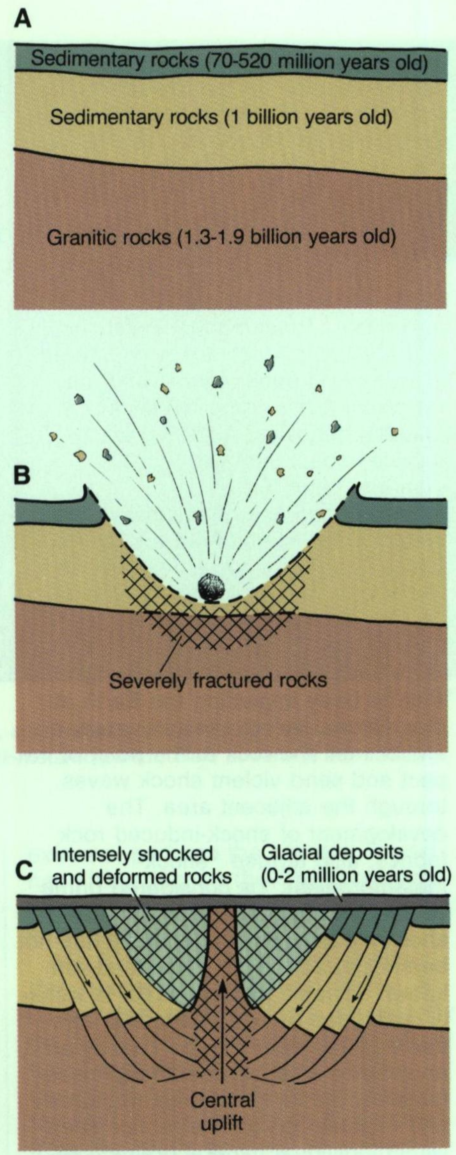
Over the years, unexpected rock sequences have been encountered during the drilling of water wells in the Manson area. Information from these wells provided the basis for the initial recognition of the Manson structure in the early 1950s. The presence of Precambrian-age igneous and metamorphic rocks (granites and gneisses) immediately beneath the glacial deposits near the center of the structure is especially noteworthy, as such rocks are found nowhere else in Iowa that close to the land surface. Thick sections of fossiliferous Cretaceous-age shales, which were deposited in the last seaway that covered Iowa, also are noted within the Manson structure. Similar shale deposits have been eroded from Iowa localities outside the Manson structure, indicating that these shales were downdropped along faults and preserved within the structure prior to their regional erosion elsewhere.

Availability of groundwater from shallow bedrock aquifers remains a problem for many residents living within the crater area, perhaps because of the widespread occurrence of the thick and relatively impervious Cretaceous shale and other shaly rocks within the Manson structure. However, water wells in the central area of the structure near the town of Manson produce naturally soft water from the fractured Precambrian rocks; this contrasts significantly with the harder, more highly mineralized groundwater produced from bedrock aquifers elsewhere in the state.

The basic features of the Manson structure were deduced in the 1950s: 1) a circular outline; 2) a central uplift of fractured granite and gneiss; and 3) a periphery bounded by faults, or vertical displacements of rock strata. Geologists at the time proposed an explosive volcanic origin for the Manson Anomaly, as it was known, but more recent studies indicate a non-volcanic explosive origin.

Small meteoroids rain into the Earth's atmosphere from outer space on a daily basis, but larger meteoroids, asteroids, or comets seldom collide with the Earth. Nevertheless, sites like Arizona's Meteor Crater, a relatively recent impact about three-quarters of a mile in diameter, prove that our planet is bombarded occasionally by larger extraterrestrial objects. Several meteorite falls have been documented in Iowa, including Marion, 1847; Amana, 1875; Estherville, 1879; and Forest City, 1890; but none of these were large enough to produce impact craters. Could Manson be a large meteoroid or asteroid impact site? What sort of evidence is present?

Two lines of evidence suggest that the Manson feature was created by the impact of a large extraterrestrial object. First, its circular structure resembles other known impact sites, which occur as fault-bounded features with a central uplift. The Manson Crater overlies a region characterized by deep sedimentary basins of Precambrian-age that flank a central belt of volcanic rocks stretching northeast-southwest across Iowa (see map). These ancient basins are filled with sandstone and mudstone deposits up to six miles thick, and were the target of the recently completed AMOCO exploration well in Carroll County (see page 11). These Precambrian sedimentary rocks, which occur at depths of about 2,300 feet outside the Manson structure, have been encountered at much shallower depths (about 100 feet) within the Manson Crater, a result of complex block-faulting. Outside the structure, these basins overlie granitic rocks at a depth of about 22,000 feet, but in the central part of the Manson Crater the granitic rocks were uplifted an estimated two



Meteor impact severely deformed sedimentary rocks, caused the uplift of deep granitic igneous rocks, and resulted in a complex crater structure now covered by younger glacial deposits. Vertical exaggeration 1.5x to four miles, to within 90 feet of the land surface — a dramatic uplift by any standard. Younger rocks of Paleozoic and Mesozoic age overlie the sedimentary basins and were severely disrupted and deformed during crater formation. These younger rocks are fractured and faulted within the crater, and locally display fault-related (cataclastic) rock fabrics. Chaotic admixtures of Precambrian, Paleozoic, and Mesozoic rocks are encountered in many well penetrations, and may represent crater-filling fall-back material deposited following an explosive impact (see sequential diagram, page 5).

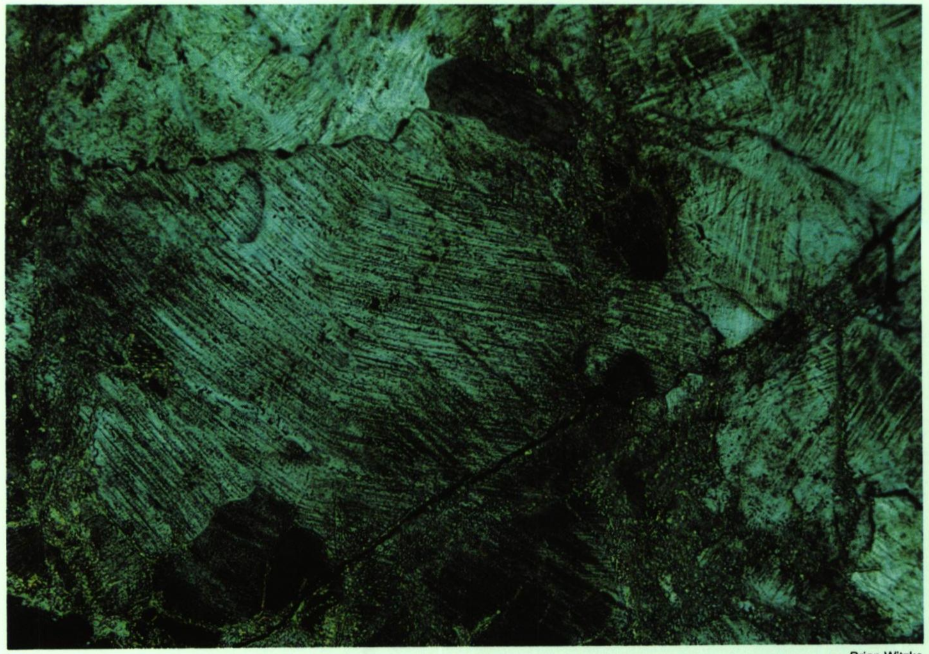
The second line of evidence for an impact origin stems from a study of unusual, shock-induced features seen within rock samples from the Manson Crater. Two rock cores drilled by the Iowa and U. S. Geological Surveys in 1953 provided these critical samples. A large body impacting the Earth at phenomenal velocity would vaporize and/or melt the rock at the point of impact and send violent shock waves through the adjacent area. The development of shock-induced rock fabrics, also termed "shock-metamorphism," is considered prime evidence for impact origin. Intense shock-metamorphism generally has not been observed to be associated with known volcanic explosions (or is weakly developed at best). Samples from the Manson impact crater display an abundance of shock-metamorphosed features, primarily complex fractures and modified crystalline fabrics seen within individual mineral grains (see photo, page 7). Fused glass from the Manson Crater also indicates that rock melting occurred near the point of impact.

The Manson Crater, also called an "astrobleme," is the largest meteor-impact site in the United States. Experimental considerations suggest that a Manson-sized impact crater (20-mile diameter) would require an impacting body estimated at about two miles in diameter. When was the Manson Crater formed? The presence of structurally disturbed Cretaceous shales within the crater indicates an age no older than Late Cretaceous time. Radiometric-age dates based on fission-track and argon-argon methods recently have been determined from the Manson samples by geologists at the U.S. Geological Survey (Charles Naeser, Michael Kunk, and others), and these dates average about 66 million years old. This age closely approximates the age of the Cretaceous-Tertiary boundary, an important global chronologic boundary that marks the extinction of many forms of life including most or all of the dinosaurs, and the beginning of the "Age of Mammals."

Nobel Laureate Luis Alvarez, his son Walter, and their colleagues at Berkeley, California, have recognized an unusual enrichment of the noble element iridium in sediments at the Cretaceous-Tertiary boundary, and in 1979 they proposed an extraterrestrial source for this enrichment. They further suggested that a large impact event may account not only for the iridium enrichment, but may have helped trigger global biologic extinctions at the end of the Cretaceous. They hypothesized that a large impact event would send enormous volumes of dust into the atmosphere, thereby blocking sunlight to the Earth's surface for a time span long enough to disrupt the photosynthetically based food chain and create a global biologic crisis. Although this hypothesis remains controversial, evidence for a major impact event at the Cretaceous-Tertiary boundary now seems incontrovertible. Iridium-enriched boundary layers have now been recognized at numerous sites around the world, and shock-metamorphosed quartz grains are noted in these boundary layers at many sites as well, particularly those in North America. The Manson impact crater has been proposed as a likely source for these widely dispersed, shocked-quartz grains.

Could the explosive impact that created the Manson Crater be responsible for the extinctions at the close of Cretaceous time? Current theory suggests that the Manson Crater, by itself, is probably not large enough to have produced a sufficient volume of dust to induce global atmospheric darkening. Nevertheless, the Manson Crater remains the only candidate large enough and with an age coincident with the Cretaceous-Tertiary boundary. Perhaps a swarm of meteoroids and asteroids impacted the Earth at that time, and Manson is but one of many contemporaneous impact sites. At the other extreme, perhaps the Manson impact had little effect on the Cretaceous extinctions, and other causes need to be evaluated.

Much remains to be learned about the geology of the Manson Crater. A cooperative study program is presently the focus of the Manson Impact Structure Team (MIST), a group of 20 geologists from across the country interested in this Iowa feature. Samples from the 1950s core will be subject to further analytical studies, including age-dating, paleomagnetism, and various petrologic examinations. It is clear to all participants that a sequence of drill cores across at least the radius of this structure is essential to form a more complete picture of the impact site's characteristics. □



Brian Witzke

Microscopic fractures through this quartz grain, seen as sets of closely spaced, parallel, and intersecting lines, are unique indicators of shock-metamorphism. Field of view is 1.3 mm.

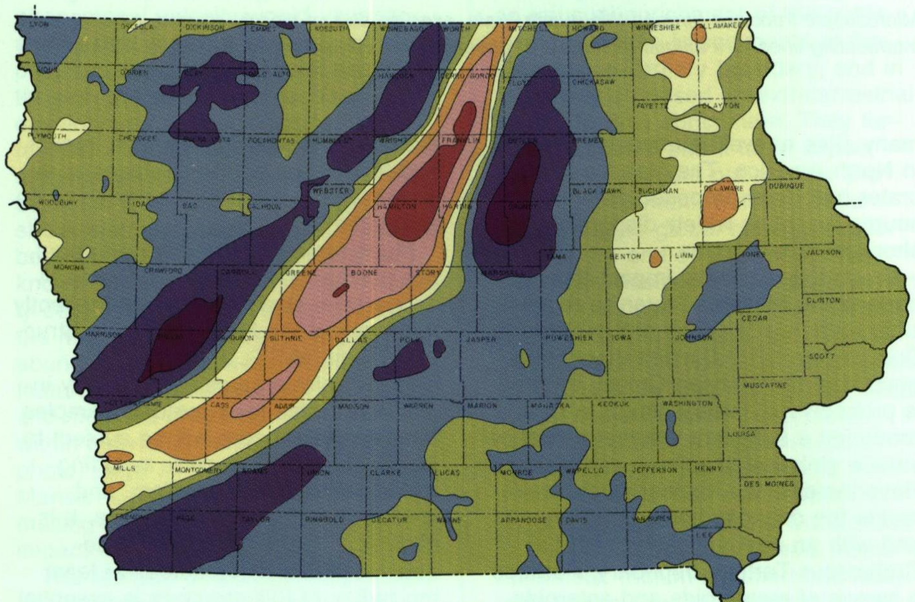
GRAVITY AND MAGNETICS:

TOOLS FOR EXPLORING THE EARTH'S INTERIOR

James D. Giglierano

Geology is a science based on direct observation of features on the Earth's surface or within reach of drilling equipment. The interior of the Earth, however, is inaccessible and information and interpretations must be made without the direct evidence normally required for scientific scrutiny.

In the last 50 years, remote sensing techniques have been developed which enable the detection and imaging of Earth properties from a distance. Many forms of energy easily pass through rock materials or are modified by rock bodies and thus can be used to derive information about the physical properties of the rock material. Such types of energy include sound, electrical currents, radioactivity, and magnetic and gravitational fields — the techniques of geophysical exploration. In Iowa, all of these techniques have been used to some degree to detect and determine properties of rock bodies buried from several feet to several miles. Only magnetic and gravity surveying, however, have been applied statewide, as these methods can be used over large areas at a lower cost than other methods.



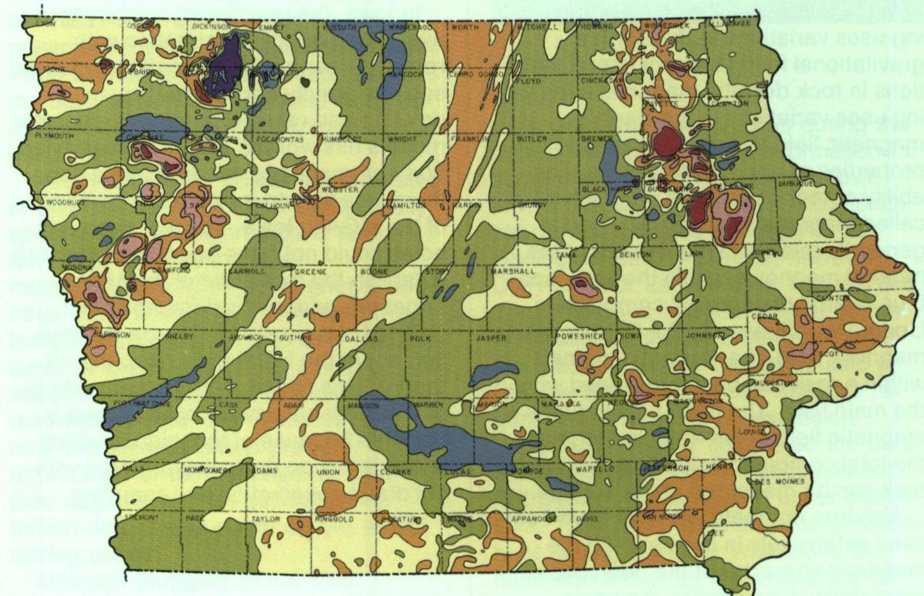
VARIATIONS IN GRAVITATIONAL INTENSITY ACROSS IOWA

maximum — minimum

The basic approach to gravity surveying is to measure variations in the acceleration of the Earth's gravity. Gravitational pull varies from one location to another because of lateral differences in rock density. Density is related to chemical composition, and thus gravity data can be used to map rock types, at least in a general way. Gravity surveying, however, only measures relative differences in gravitational acceleration, thus requiring some direct geologic data to give the interpretation a starting point.

The accompanying figure on page 8 shows the Bouguer gravity anomaly map for Iowa. The Bouguer (pronounced boo-GAY) anomaly is the gravity value that remains after corrections are made for known variations in the Earth's gravitational field. Bouguer gravity values in Iowa range from about −110 to +65 milligals. The unit of measure for gravity is the "gal," which is named for Galileo. Positive anomalies, or areas with stronger gravitational intensity, contrast clearly with the negative anomalies, or areas of weaker gravitational intensity. The map displays an overall moderately negative anomaly which is typical for continental areas.

This map also shows numerous individual anomalies, many interpreted to be igneous rock bodies that were pushed up into the older crust between 2.5 billion and 1.1 million years ago. The most striking feature on the map is a curvilinear high which extends across the state from Council Bluffs to Mason City. This feature is commonly referred to as the Midcontinent Geophysical Anomaly or MGA. Actually, the MGA can be traced on gravity maps from northern Michigan, through Minnesota, Iowa, and Nebraska to central Kansas.



VARIATIONS IN MAGNETIC INTENSITY ACROSS IOWA

maximum — minimum

Its most unusual expression, however, is across Iowa, and includes extreme lows directly adjacent on either side.

Wells drilled into the MGA high indicate that it is caused by dense igneous rocks, while the lows are believed to be deep basins of lighter sedimentary rocks. It is theorized that the MGA is the remnant of a continental rift which began to form 1.2 billion years ago. A rift is a zone where the Earth's crust begins to separate, and molten igneous material from the deeper mantle moves to the surface to fill in the void left by the rifting. If the rifting is successful, a new ocean basin is formed between the two pieces of rifted continent. For some unknown reason, the MGA rift stopped and no ocean basin was formed. All that is left is the initial igneous and sedimentary material associated with the rifting process. The deep AMOCO well in Carroll County was drilled to test the oil and gas potential of these rift sediments (see page 11).

In the same way that gravity surveying uses variations in the Earth's gravitational field to detect lateral variations in rock density, magnetic surveying uses variations in the Earth's magnetic field to detect the magnetic properties of buried rock bodies. The ability of rock to become magnetized is called magnetic susceptibility and is generally related to the amount of the mineral magnetite within the rock, and thus related to chemical composition. Under the influence of the Earth's main magnetic field, the magnetic grains within a rock can become aligned with the main field. The main field induces a magnetic field in the rock and together, the total combined field of the Earth and rock can be measured at the surface.

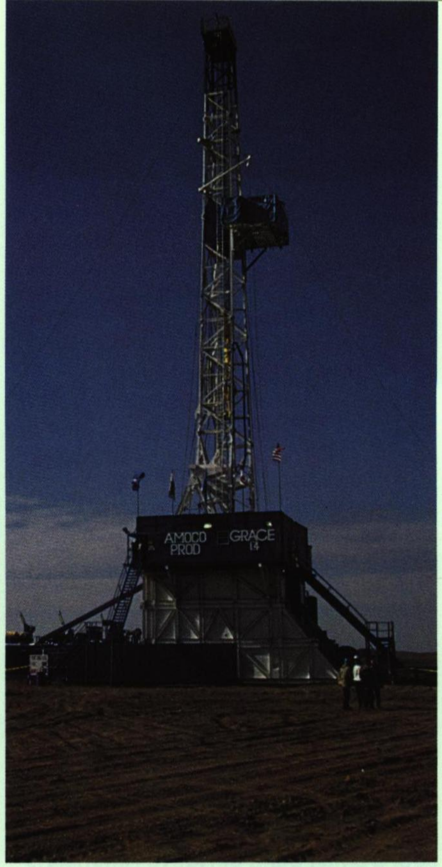
Airborne magnetic surveys have been used extensively in Iowa to map the magnetic character of the deep basement rocks. Like gravity, the basic application of this technique is to measure the total Earth magnetic field, remove predictable variations, and display the remaining anomaly values.

The map on page 9 is a representation of the magnetic anomalies in Iowa. Values used in magnetic surveys have no plus or minus signs, nor do they have any fixed absolute value. They only indicate the relative difference in magnetic intensity from one spot to another on the Earth's surface. The MGA, though less pronounced than on the gravity map, still appears as a distinct curvilinear trend. The sharper linear features along the MGA are probably major faults. Other crustal features show as distinct bodies similar to those on the gravity map, though not always in corresponding geographic locations. The deep lows adjacent to the gravity high have subtle magnetic anomalies within them. They are less distinct but similar in size and shape to those farther away from the MGA, and may indicate deeply buried bodies that are still "visible" through the thick sedimentary rocks.

In Iowa, the practice of combining available geologic information with reconnaissance geophysical techniques, such as gravity and magnetics, to develop and refine a number of geologic models has worked well. Before gravity and aeromagnetic surveying was done, there was little to indicate the presence of the MGA in Iowa. The few deep drill holes could not have been used alone to establish the existence of the MGA. Together, geophysical methods and drilling have provided enough information about the MGA to develop the rift theory. This measure of understanding of the deep basement rocks in Iowa is possible because of techniques which allow detection and measurement without direct observation and sampling. □

HISTORIC OIL TEST COMPLETED

Raymond R. Anderson



Don Koch

On October 19, 1987, the final surface plug was set, marking completion of the AMOCO M.G. Eischeid #1 oil test. The well, located near Halbur in Carroll County, was completed 208 days after drilling began at the Eischeid farm on March l6th. This was the second well to explore the petroleum potential of the one-billion-year-old rocks of the Midcontinent Rift System (the first was drilled by Texaco in Kansas in 1985). The Eischeid #1 reached a final depth of 17,851 feet, easily eclipsing Iowa's previous deepest well, the #1 Wilson in Page County (5,305 feet deep, drilled in 1930). In fact, the Eischeid #1 is the deepest drill hole in the central Midcontinent.

Nearly 20 million dollars was invested in this historic project. AMOCO initially spent about 10 million dollars to acquire and process seismic, magnetotelluric, gravity, magnetic, and other data. From this information they leased petroleum rights to over 800,000 acres of Iowa farmland at a cost of about 5 million dollars, including renewals to date. The decision to drill near Halbur was based primarily on interpretation of the geophysical data (see page 8), and an estimated 4.8 million dollars was spent on the actual drilling project.

Although plugging of the M.G. Eischeid #1 well indicates that AMOCO did not encounter economic quantities of petroleum, a company representative described the well as "successful." Exactly what was encountered during the drilling will not be public information for some time. In accordance with Iowa law, AMOCO has provided a complete set of rock samples and logs to the Geological Survey Bureau; however, DNR Director Larry Wilson has granted the company a two-year period of confidentiality on the well. Information on the Eischeid #1 will become public on October 29, 1989, unless AMOCO requests and receives an extension.

AMOCO recently completed the third exploration well into the Midcontinent Rift System in Michigan's upper peninsula. They have discussed the possibility of drilling a well in Wisconsin, but have also indicated the probability of drilling another deep well in Iowa in the near future. □

THE ROLE OF GEOLOGY IN SHAPING THE ARCHEOLOGICAL RECORD

E. Arthur Bettis III

Insights into locating and interpreting remains of ancient American Indian cultures are gained by mapping patterns of erosion and deposition in Iowa's valleys.

Beginning about eighteen centuries ago, a small band of Native Americans began wintering over in a gully in the Loess Hills, about twelve miles northeast of the junction of the Big Sioux and Missouri rivers. These people were hunters and gatherers who moved with the seasons in order to obtain food and other necessary resources. Deep gullies in the area provided an ideal winter camp — abundant wood for heat and cooking, shallow depths to water, and shelter from winter storms. During their stay the group lived in an oblong structure made from branches pushed into the ground and covered with hides. This house, which was divided into two rooms with a hearth in each, was probably occupied by an extended family. When the weather warmed and the snow began to melt, the group broke camp and moved to the spring hunting area. Their accumulated garbage and abandoned shelter in the gully were soon buried by silt deposited during spring and summer runoff. This scenario was repeated countless times during the next ten centuries, and the remains of successive occupations were buried as the gully continued to fill with sediment. In time, this wintering area was abandoned in favor of other, deeper gullies which afforded greater protection from the elements.

In June 1976, the Native Americans' former winter camp (known to archeologists as the Rainbow Site) was discovered while planning for the Held Creek Watershed, an erosion and gully-control project in southwestern Plymouth County managed and funded by the U.S. Dept. of Agriculture, Soil Conservation Service (SCS). Since passage of the National Historic Preservation Act of 1966 and the National Environmental Policy Act of 1969, environmental impact statements (EIS) are required for federally funded projects. The purpose of an EIS is to ensure that the environment is not being adversely impacted by the project, or if it is, to mitigate the impact. Part of the environmental assessment involves inventory and evaluation of the historic and prehistoric cultural resources within a project area. Archeologists usually walk over plowed fields and dig shallow test pits searching for artifacts and other evidence of prehistoric human activity. These techniques work well in upland locations and other portions of the landscape where prehistoric sites are not deeply buried. In valleys, however, deep burial is common, and the difficulty of the archeologists' job is compounded.

Since 1976 geologists working with archeologists in Iowa have begun to unravel the sequence of geologic deposits in which the archeological record is preserved. This work has brought to light little-known aspects of culture history and has raised questions about the distribution and abundance of archeological sites.

It is important to realize that the archeological record is a product of both cultural and geologic factors. Where and when people engage in activities and leave behind artifacts is a cultural phenomenon. Once a site is abandoned, however, whether or not it is preserved and becomes part of the archeological record is a geologic phenomenon. This aspect of preservation is especially important in valleys, where stream erosion regularly removes older deposits. Equally important in assessing the archeological record is the potential for younger deposits to bury sites and prevent their detection. These two geologic factors, erosion (destruction) and burial, profoundly shape the archeological record as well as our perceptions of that record.

Dave Benn

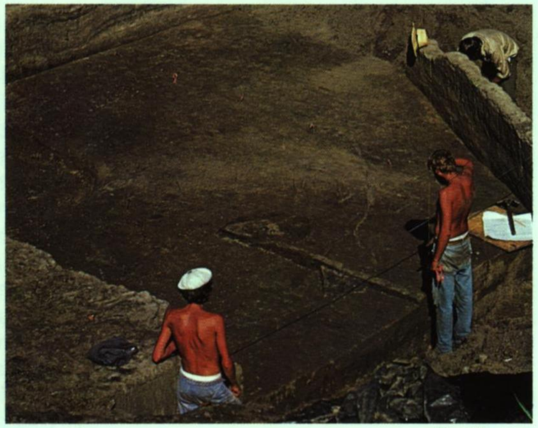
Changing styles in decorative patterns of prehistoric pottery can date both cultural sites and geologic deposits enclosing them.

In western Iowa the inventory of known archeological sites is dominated by those less than 2,000 years old. Scattered evidence, however, indicates that the region was occupied at least 8,000 years ago. Following discovery of the Rainbow Site, the SCS initiated a study aimed at dating episodes of gully growth and filling during the last 10,500 years, and tracing distinct gully fills throughout the region (see *Iowa Geology*, No. 8, 1983). Six distinct fills were present in the area. Each of these accumulated during a specific interval of time and therefore has specific archeological associations. Mapping the distribution of these deposits permits assessment of the *geologic* potential for a valley to contain archeological remains from the various culture periods defined by archeologists. This assessment enables archeologists to determine which methods are needed to locate cultural resources in an area, and also helps planners avoid impacting high-potential areas, thereby decreasing the need for costly mitigations. The western Iowa studies demonstrated that abundant remains of pre-2,000-year-old occupations are deeply buried in valleys and alluvial fans. The systematic locating of these sites and our subsequent increase in knowledge of these early inhabitants represent a frontier in Iowa archeology.

Another example from this rapidly expanding field of archeological geology is the combined archeological and geological investigations of the central Des Moines River valley, undertaken to provide the U.S. Army Corps of Engineers with cultural resource information needed for planning recreational development and interpretive programs in the Saylorville Lake area. Since the 1960s many prehistoric sites have been recorded in this area, but most date from the last 2,000 years. Few deeply buried and stratified sites were recorded prior to the 1984 geologic studies. Stratified sites are especially important to archeologists because they can show successive changes in diagnostic artifacts which can be used to date sites that are not stratified. In addition, bone,

Dave Benn

Dave Benn



Dean Thompson

Within the strata revealed in this large excavation pit at the Rainbow Site in Plymouth County were several superimposed house structures. Each dark, organic-rich band indicated a winter-long encampment in this western Iowa gully. Successive occupation sites were buried as the gully continued to fill with silt.

Above: *Charcoal, ash, and fired earth are seen in the cross-section of a shelter's hearth.* Below: *Note the dark, circular outline of the shelter's floor.*

ceramics, and earthen features such as storage pits are better preserved in buried sites.

Five valley-landform areas were recognized in the Saylorville Lake area; each of these contained deposits that accumulated during a specific portion of the last 11,500 years. Just as in the western Iowa gully fills, archeological associations, and the geologic potential for buried sites from individual culture periods, varied in each landform area. Combining geological mapping with the archeological study revealed that sites older than 2,000 years are not rare, but *are* rarely evident at the present land surface. Now archeologists know where in the valley these sites are likely to be preserved and that subsurface methods are needed to find them. It was also discovered that even the youngest sites in the valley can be buried and thus "invisible" from the surface using traditional site-locating techniques. Geologic investigations revealed that extensive deposits of Historic floodplain alluvium covered previously undiscovered sites of the Oneota Culture, the most recent prehistoric occupants of the valley above Des Moines. These studies have improved our understanding of the culture history of the Saylorville Lake area and have pointed toward productive avenues of future research.

Archeological geology continues to grow in its applications and scope in Iowa and elsewhere. It holds promise for unravelling some enigmas of archeological site distribution and culture history. The results of archeological-geology studies benefit archeologists, planners, conservationists, and, through more effective use of federal funds, all taxpayers. □

ROCK AND MINERAL COLLECTING

Paul J. Horick

Tim Kemmis

Specimens of calcite show an iridescent play of color from their crystal faces.

There are many places to visit in Iowa that will spark the interest of rock and mineral collectors. Scenic outcrops along stream valleys, exposures at roadcuts and quarries, as well as sand and gravel bars and pits along rivers provide good collecting grounds for a surprising variety of rock types and associated minerals and fossils.

The glaciers that invaded Iowa in the geologic past left thick deposits of pebbly glacial drift covering the state's bedrock surface, and glacial meltwaters concentrated deposits of sand and gravel along the state's river valleys. Gravel bars and gravel pits are logical starting points for many collectors, as these sites have a wide range of stones to attract the eye. The beautifully banded Lake Superior agates, as well as other agates, jaspers, and cherts, are excellent materials for polishing (see cover), and can be found in gravel deposits along major eastern Iowa rivers.

Beneath the upland glacial deposits lie much older, fossiliferous sedimentary bedrock formations. Mineralized veins and vugs found in limestone quarries and exposures contain a large assortment of minerals such as barite, calcite, chalcedony, dolomite, fluorite, galena, glauconite, goethite, limonite, marcasite, millerite, pyrite, quartz, sphalerite, and smithsonite. Certain fossils, notably *Hexagonaria* and silicified *Lithostrotion* corals are also found in limestone and are prized by collectors because they can be cut and polished. Varieties of travertine also occur in Iowa as flowstone deposits coating crevices in carbonate bedrock.

Shale exposures and pits are noteworthy for well-developed selenite (gypsum) crystals at many places in southern and western Iowa. Abandoned coal strip-mines also yield specimens of petrified wood and fossil plants. Calcareous shales such as the Warsaw formation in Des Moines, Henry, Lee and Van Buren counties are the principal setting for geodes (see *Iowa Geology*, No. 12, 1987). These spherical rocks with chalcedony shells and hollow interiors are easily extracted from the enclosing shales, and when split open they exhibit sparkling crystals of quartz or calcite along the cavity walls. In 1967, these southeast Iowa geodes were designated by the General Assembly as Iowa's "state rock."

Though rock and mineral collecting is often regarded as a rather solitary activity, Iowa has an active group of "rockhounds" and lapidarists as exemplified by the many rock and mineral, or gem and lapidary, clubs scattered around the state. As of 1982 there were 26 such organizations listed in the "Directory of the Midwest Federation of Mineralogical and Geological Societies." The activities that make joining a local rock and mineral society worthwhile include the exchange of information on collecting locations, trading, buying and selling specimens, educational programs, and regular meetings with others who have similar interests. Members often know which landowners to contact for permission to collect on private property. Experienced collectors also know where to find the most interesting specimens for cutting and polishing, and making cabachons and other ornamental jewelry. Some Iowa collectors have accumulated valuable collections of rocks and minerals, with many beautiful and rare specimens suitable for display in museums.

Much practical information on Iowa rocks and minerals also can be obtained by visiting exhibits at Iowa Hall in the University of Iowa Museum of Natural History and in museums at Cornell College, Drake University, Iowa State University, University of Northern Iowa, as well as the Davenport Public Museum, and the Waterloo (Grout) Museum. The Geological Survey Bureau in Iowa City has lists of rock and mineral clubs, as well as maps and educational materials on rocks, minerals, and fossils that the beginning collector will find helpful. Recommended reading materials include: Anderson, Wayne I. (1983) *Geology of Iowa*: Iowa State University Press, 268 p.; Horick, Paul J. (1974) *The Minerals of Iowa:* Iowa Geological Survey, Educational Series 2, 88 p.; Rose, J.N. (1967) *The Fossils and Rocks of Eastern Iowa:* Iowa Geological Survey, Educational Series 1, 147 p.; and Wolf, R. C. (1983) *Fossils of Iowa, Field Guide to Paleozoic Deposits:* Iowa State University Press, 298 p. □

Tim Kemmis

Tim Kemmis

Above: *A large Keokuk geode is lined with pink and gray quartz crystals.* Below: *A specimen of Mahaska County limestone contains crystals of white dog-tooth spar (a variety of calcite) and pyrite ('fool's gold').*

SAND AND GRAVEL RESOURCES OF IOWA

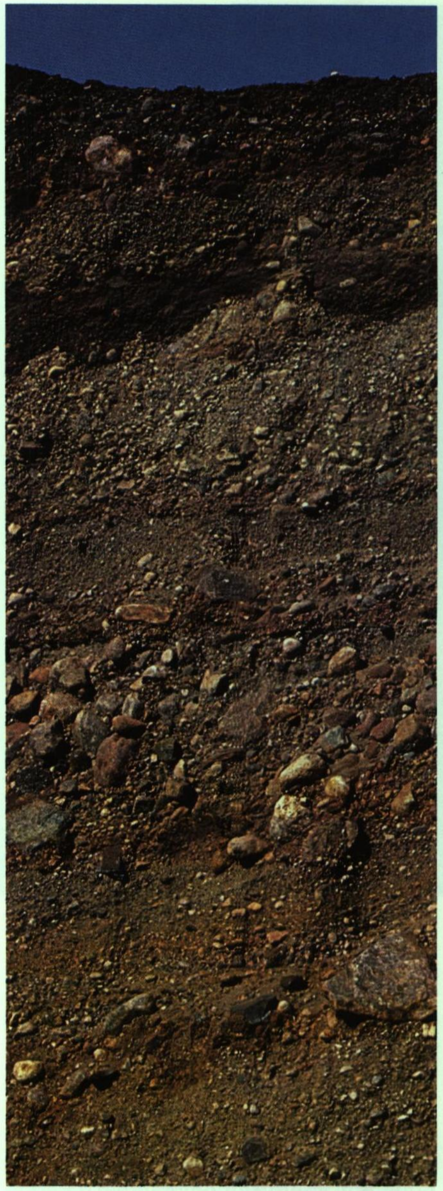
Timothy J. Kemmis
Deborah J. Quade

Sand and gravel are resources commonly taken for granted, yet they represent one of Iowa's largest mineral industries. Over 13 million tons of sand and gravel, valued at over 34 million dollars, were marketed by Iowa producers in 1986 according to the U.S. Bureau of Mines. These resources were used primarily for maintenance of the state's gravel road system, for aggregate to be mixed into concrete, and for subgrade material in highway construction. Some of these uses have specific requirements related to aggregate size, sorting, and quality. The Iowa Department of Transportation publishes aggregate specifications for its various projects.

Since nearly all of Iowa's sand and gravel resources originated as sediment deposited by streams, most sand and gravel operations are located in stream valleys. The volume and velocity of flowing water as well as the availability and size of sediment for transport vary considerably in stream systems. Typically, cobble- and pebble-sized gravels move only short distances before deposition, and these deposits contain poorly sorted, coarse material. Finer-grained pebbly sands are deposited farther downstream from their source areas (bedrock outcrops or glacier margins). Still smaller particles (sand, silt and clay) may travel long distances before deposition, and these deposits are often better sorted.

Iowa' s river system is a complex hierarchy of streams ranging from small rills on hillslopes to the broad expanses of the Mississippi and Missouri rivers on the state's eastern and western borders. These streams connect to form a drainage network across the state's landscape. The stream valleys consist of two basic components: floodplain and terraces. The floodplain is the lowest part of the valley, and consists of the modern stream channel and that part of the valley floor covered with water when the river is at flood stage. Terraces are relatively flat remnants of former floodplains now elevated along the valley because the river downcut (eroded) to lower levels.

The characteristics of Iowa's stream valleys and their sand and gravel resources change significantly within the different physiographic regions of the state (see *Iowa Geology*, No. 10, 1985). For example, western and southern Iowa valleys are part of a well-connected drainage system cut into older glacial materials deposited several hundred-thousand years ago. These valleys contain extensive, high, sandy and gravelly terraces. Many of these terraces are mantled with windblown silt (loess) originating from the Missouri Valley during late-glacial time. Valleys of the Iowan Erosion Surface of northeastern Iowa are also part of an integrated drainage system, but most of the valleys are wide and shallow, and the loess cover is generally thin or absent. Extensive sand and gravel deposits in these valleys were derived from older glacial materials and bedrock during the erosional development of this region. In north-central Iowa a youthful, poorly developed stream network was established following the glacial advance which occurred 14 to 12 thousand years ago. These valleys were affected by meltwater floods from stagnating glaciers. River valleys of extreme northeastern Iowa are much different from other valleys in the state. They are deeply carved into bedrock and form spectacular bluffs along such rivers as the Upper Iowa, Yellow, and Turkey. Thick deposits of sand and gravel occur in high terraces within these valleys. These differences in location, age, and source of sand and gravel have made a systematic, state-wide study of this resource difficult.


Tim Kemmis

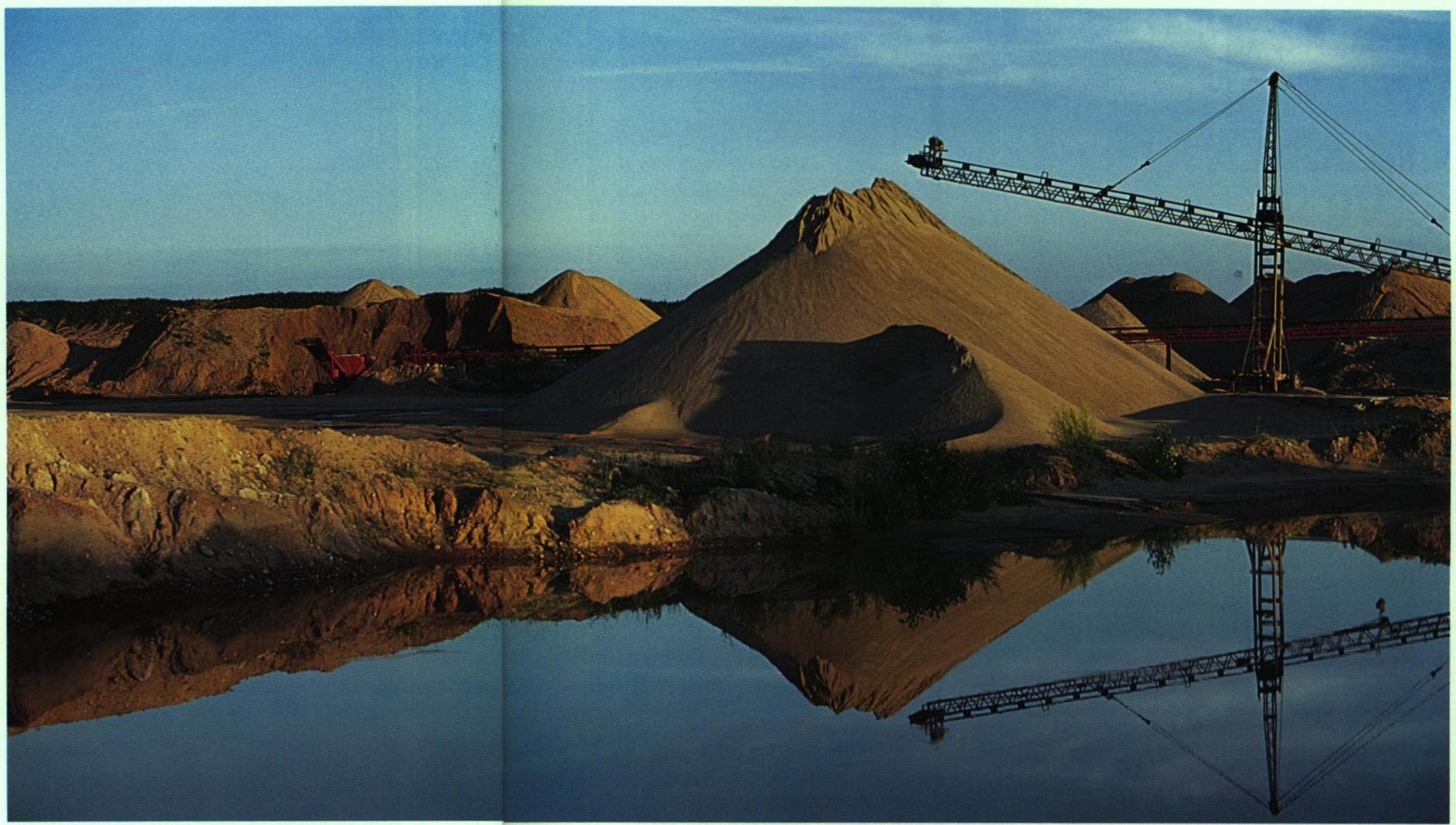
Patterns of sediment deposition in this Emmet County gravel pit indicate shifts in stream-flow direction, volume, and velocity associated with the melting of north-central Iowa glaciers.

The variability in Iowa's stream deposits also reflects past changes in river conditions along different reaches of the valleys and past shifts in climate. For example, valley landscapes, as well as sand and gravel deposits, were affected by increased discharge from incoming tributaries, the proximity to former glacial meltwater sources, and local variations in shallow bedrock uncovered along the valley. In addition, river environments and associated deposits changed significantly as glacial climates during Wisconsinan time (last glacial) shifted to non-glacial conditions during the Holocene (which includes the present). During the Wisconsinan, valleys were flooded by high discharges of sediment and water, while during the Holocene, peak sediment and water discharges have been significantly less, with reduced fluctuations and a predominance of overbank sedimentation of fine-grained deposits.

Sand and gravel deposits from former stream valleys also occur buried within the sequence of upland glacial deposits across the state. Where not too deeply buried, these deposits are used as sand and gravel sources, and they show the same types of variability as described for modern stream valleys. The occurrence of these deposits is difficult to predict, however, because of their burial and limited distribution.

Other important upland sources of sand and gravel include distinctive glacial landforms on the Des Moines Lobe, features known as "kames" and

Sand and gravel are sorted into different sizes for various uses at this Worth County operation along the Shell Rock Valley. This major Iowa resource is used primarily for road construction and maintenance.



Tim Kemmis

"eskers." Kames, such as Ocheyedan Mound State Preserve, are round or elliptical hills composed predominantly of sand and gravel, while eskers, such as Caylor Prairie State Preserve, are linear or slightly sinuous ridges of sand and gravel. Both of these landforms were deposited in direct contact with melting ice, probably in glacial tunnels or crevasses. Kames and eskers can be good sources of sand and gravel, but they typically show abrupt, unpredictable changes in grain size, and may have appreciable quantities of unwanted, fine-grained stream, lake, or mudflow deposits.

For sand and gravel producers, concerned with obtaining the resources economically, these changes in the character of sand and gravel along a valley necessitate using different methods of extraction. End-loaders and draglines are used to excavate shallow deposits, less than 20 feet below the surface and usually above the water table. Most of these deposits are located either on the higher terrace levels of stream systems or in the isolated, upland kames and eskers. Sand and gravel from these locations is usually coarse, poorly sorted, weathered, and may contain organic material (coal, wood, peat, fossil bones and teeth). Such deposits are used primarily for asphalt aggregate as well as road base and surfacing material because of their unsuitability for concrete aggregate. These operations are not as cost effective as the larger, more permanent dredge operations because of increased hauling and loading costs. However, shallow deposits are excellent sources for seasonal excavation or when aggregate is needed for nearby gravel roads and highway projects.

Dredge and dragline operations, on the other hand, are used to excavate thicker (20 to 60 + feet) stream-valley deposits of sand and gravel which often occur below the water table and are buried by finer-grained material. Dredge operations are the most cost-effective method to remove these extensive, buried, water-saturated sand and gravels. Material excavated from such operations is finer grained, less weathered, and contains nearly uniform particle sizes, thus making it quite suitable for concrete aggregate.

Once a sand and gravel operation is finished, the excavation site may be acquired by a county park system to provide swimming and fishing for local residents, or may be converted into a housing development with waterfront lots. Unfortunately, numerous abandoned sand and gravel pits have been used for trash dumps. Such pits can present serious environmental hazards since most of them are connected to strata which provide drinking water to wells. Proper management of abandoned sand and gravel pits is needed to avoid environmental hazards in the future.

In summary, sand and gravel constitute an important resource used extensively in every Iowa county. While complex variations exist among the state's sand and gravel deposits, further geologic investigations will enable better assessments and more economical use of this important resource. □

AG-DRAINAGE WELLS AND GROUNDWATER QUALITY

Robert D. Libra

Iowa agriculture benefits from two important natural resources, the rich soils that blanket the landscape and sufficient precipitation, in most years, to produce large crop yields. While precipitation is essential to farmers, many of Iowa's soils, especially in the north-central part of the state, are poorly drained and at times contain excess water that can hinder field operations or ruin crops. In these areas, farm fields are often artificially drained by buried tile lines leading to ditches or to streams. Another, but less common, method is the agricultural drainage well, a shaft which funnels excess water directly underground. The upper parts of these wells are fed by tile lines; other wells also are designed to receive surface runoff. Ag-drainage wells are usually 5 to 10 inches in diameter and are cased from the land surface to the top of bedrock. They vary in depth from 30 to over 300 feet. There is currently no accurate count of these wells in Iowa, but most estimates suggest 600 to 700 with the greatest concentration in Humboldt, Pocahontas, and Floyd counties.

Ag-drainage wells are particularly efficient at removing excess water when drilled into shallow, creviced and fractured limestones. Such limestones, however, are also capable of yielding large quantities of groundwater to pumped wells. Over the eastern two-thirds of Iowa, most private wells rely on these shallow carbonate aquifers for drinking water.

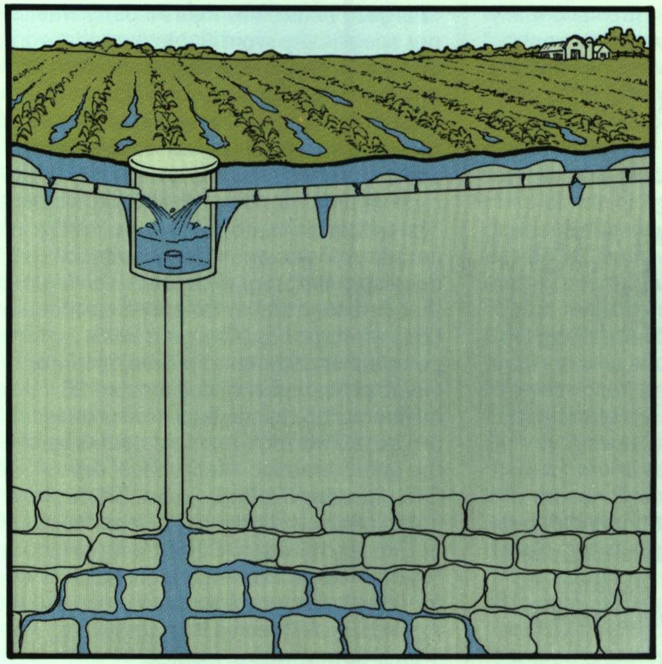
Since chemical fertilizers and pesticides in groundwater have been a growing concern over the past decade, attention has focused on ag-drainage wells. Water percolating into tile lines or flowing directly to these wells contains relatively high concentrations of nitrate, pesticides, and bacteria. Ag-drainage wells deliver this water directly into aquifers utilized by local residents. Although studies have documented this degradation of groundwater quality by ag-drainage wells, our understanding of the process is still incomplete.

Researchers from Iowa State University sampled numerous private wells in Pocahontas and Humboldt counties. In parts of these counties, the carbonate aquifer tapped by rural residents for drinking water lies beneath 50 feet or more of clay-rich glacial deposits. In these areas, the thick, slowly permeable, glacial deposits protect the underlying aquifer from contaminants infiltrating from the surface, and nitrate concentrations in water wells should be relatively low. This was found to be true where ag-drainage wells are not present. Nitrate concentrations were significantly higher, however, where numerous drainage wells are present in these protected areas. While the presence of these wells caused higher nitrate concentrations, not all water wells near drainage wells reported high nitrate; in fact many were quite low.

During 1985-1986, the Geological Survey Bureau conducted a similar study of the effects of ag-drainage wells on groundwater quality in Floyd County. Similar results were found. Both studies suggest that some — but not all — water wells located near a concentration of drainage wells will contain relatively high levels of nitrate, and occasionally pesticides.

The Floyd County study also attempts to explain why all wells located near ag-drainage wells are not affected equally. A nested cluster of four monitoring wells was drilled at a site in a protected bedrock area southwest of Charles City, where many drainage wells are present; a 305-foot-deep drainage well was located just 500 feet away. The four nested wells varied in depth from about 80 to 350 feet. During a long dry spell early in the project, nitrate and pesticides were rarely detected in the monitoring wells. Spring of 1986 brought a large snowmelt and heavy rains; surface runoff developed, and tile lines that had not flowed for months began to discharge large volumes of water into the drainage wells. During this period, nitrate concentrations in the deepest and shallowest monitoring wells increased sharply. Pesticides were also detected in these wells, although different products were present in each. Sampling of the water entering nearby drainage wells demonstrated that the monitoring wells were receiving water from different drainage wells. The other two monitoring wells contained neither nitrate or pesticides, even during this wet period.

So, do ag-drainage wells affect groundwater quality? The answer is a definite yes. The magnitude and location of the effect, however, depend on the depths and casing of both drainage wells and water wells, and on the complexities of groundwater flow in fractured rock aquifers. □



Ag-drainage wells remove excess water from farm fields in the low-relief landscapes of north-central Iowa. Drainage water carrying nitrate, bacteria, pesticides, and sediment is funneled directly into limestone formations that are widely used as sources of drinking water.

OIL OVERCHARGE FUNDS
TARGETED FOR GROUNDWATER PROTECTION

Larry L. Bean

Greater energy efficiency on the farm, in methods of waste-disposal, and through improved resource information can help protect Iowa's groundwater.

The link between investments in energy efficiency and environmental protection was acknowledged recently when oil-overcharge refunds received by Iowa were appropriated for energy-related elements of Iowa's 1987 Groundwater Protection Act. The state's comprehensive groundwater protection strategy is a ten-year program estimated to cost over 200 million dollars. The energy elements of this plan will be funded for the first five years with 17.5 million dollars of oil-overcharge money.

In response to the Arab oil embargo, the United States imposed price controls on crude oil and petroleum from 1973 to 1981. A number of suits were filed against oil companies for overcharging customers during that period. In the settlement agreements and court orders that followed, the companies were directed by the U.S. Department of Energy, or by the courts, to make restitution to those overcharged. Where the injured party was not specifically identifiable (i.e., the general public), the companies were to pay the U. S. Treasury, the Department of Energy, or individual states. Iowa has received nearly 44 million dollars from petroleum settlements, and could receive another 10 to 12 million dollars. These funds must be spent on energy conservation or energy-resource development programs, and in a way that demonstrates a balanced restitutionary program to the general petroleum customer. To date, the Iowa General Assembly has allocated 26.5 million dollars for energy-conservation projects. This includes initial funding of the energy-related elements of the Groundwater Protection Act. Through negotiations with the U.S. Department of Energy, the Iowa Department of Natural Resources received approval for three basic programs.

Agricultural-Energy Management: This program was allocated $12,260,000 in the five-year plan, and will demonstrate and facilitate farm-management practices that conserve energy, enhance the efficiency of agricultural production, and provide environmental protection. Best-available-technology crop production practices will be implemented through a statewide field-demonstration and education program. The development of agricultural and wood resources for biomass energy production also will be promoted.

Energy savings will result as less fuel is needed for tillage and grain-drying, and petro-chemical based fertilizers and pesticides are used more efficiently. The strategy outlined in the Integrated Farm-Management Demonstration Project includes the monitoring of water-quality to demonstrate the losses/inefficiences of current ag-chemical use and to document the occurrence of ag-chemicals in rural groundwater. These issues of chemical, hence economic, inefficiencies/losses and drinking-water quality are the two most salient issues to the farm family (as shown by Iowa sociologic studies). Demonstration of these facts is a prerequisite to the adoption of ag-energy saving technologies.

In relation to the goals of the Groundwater Protection Act, this program will provide: public education on energy conservation and environmental protection; adoption of farming practices that protect soil, surface water, and groundwater resources, as well as conserve energy; and an understanding of the extent of groundwater problems in the state. These projects will also provide information for additional efforts to be carried out under the Groundwater Protection Act.

Waste-To-Energy, Solid-Waste Management: This program was allocated $5,010,000 in the five-year plan, and will demonstrate and implement energy recovery from municipal and county sources of solid-waste in Iowa. The 1986 General Assembly directed state and local governments to develop alternatives to landfills. This program will support studies for refuse-derived fuel, modular incineration, mass burn, source reduction, and recycling programs.

The demonstration program must also include the evaluation of current waste-disposal practices, including the hidden costs involved with closure of landfills and remediation of related problems, such as groundwater contamination. These factors must be evaluated to clearly show the potential economic viability and environmental improvement of these waste-reduction programs. Education programs also will be developed to involve the public in energy conservation, waste disposal, source reduction, and recycling.

Energy-Resource Development: This program was allocated $230,000 in the five-year plan, and will develop and demonstrate the DNR-Geological Survey Bureau's capability to implement a natural-resources Geographic Information System (GIS), which will be used to enhance energy-resource development. The project will use digital procedures to compile resource mapping data, subsurface information, and geophysical modeling data for natural-resource planning and evaluation.

As mandated in the Groundwater Protection Act, this program will allow DNR to initiate the development of a natural-resources GIS data base. Much of the information in this data base is also required for groundwater protection or other resource planning/protection activities. □

Agricultural-Energy Management	$12,260,000
Waste-to-Energy Solid-Waste Management	$5,010,000
Energy-Resource Development	$230,000

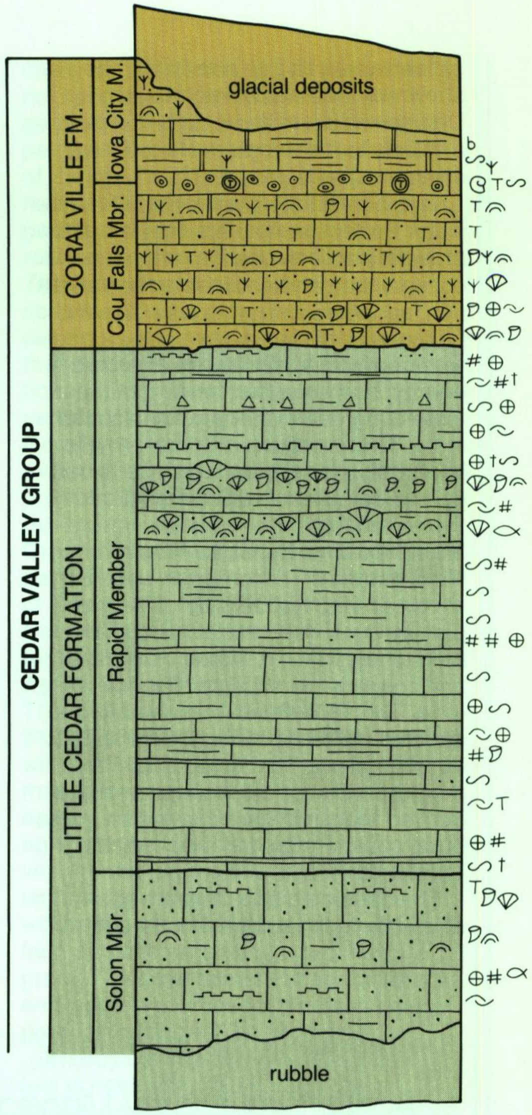
TYPE SECTIONS:

THE FORMAL NAMING OF ROCK UNITS

Bill J. Bunker

To describe an area's geologic setting and its relation to other geographic areas, geologists must first catalog the sequence of rock strata. Rocks are categorized into basic mappable units, which in order of increasing rank are termed "member," "formation," and "group." The word "mappable" indicates that a rock unit is defined on the basis of physical characteristics that can be distinguished by geologists in the field. Rock type, color, grain size, and fossil content are common parameters upon which the definition of a stratigraphic unit is based.

The rules of stratigraphic nomenclature require the designation of a "type section" for each rock unit named. A type section is the originally defined sequence of strata described for a given locality or area (American Geological Institute, *Glossary of Geology*). It serves as an objective standard with which to compare geographically separated portions of the stratigraphic unit. Preferably it is a site where the rock unit is exposed in its entirety, in contact with both overlying and underlying rock units. While there is only one type section permitted for any given unit, any stratigraphic section that can be shown to have physical continuity with the type section and is compositionally similar can be included within the named rock unit and may serve as a "reference section."



A type section is located where a rock unit is first named and described in the geologic literature. The name of the stratigraphic unit is generally taken from the name of a local geographic feature or town, commonly combined with the appropriate term for its rank (e.g., the Prairie du Chien Group, the Gilmore City Formation, and the Ft. Atkinson Member) or its lithic type (e.g., Dakota Sandstone and Maquoketa Shale).

Brian Glenister

In some instances geographic names have been derived from nearby rock outcrops. For example, in an 1866 lecture at the University of Iowa, the visiting Swiss naturalist, Louis Agassiz, emphasized the significance of fossil coral accumulations in Devonian-age limestones in the Iowa City area. Several months later, coral-rich rocks were encountered during the construction of a mill along the Iowa River west of Iowa City. The State Press (December 19, 1866) reported this event and the subsequent naming of a new town, Coralville, for these well-preserved fossil corals. In 1912, this coral-bearing limestone was, in turn, named the "Coralville," and is now recognized as a formation within the Cedar Valley Group (see graphic column and photo of Conklin Quarry, site of the Coralville type section and reference section for the Rapid and Solon members).

In another example, the town of Galena, Illinois, is named for the mineral galena, a lead ore extensively mined in the Upper Mississippi Valley during the last century. Galena, Illinois, is also the location of the type section for the Galena Group, a widespread Middle Ordovician-age carbonate rock unit.

Geologists use maps and cross-sections, which are dependent on type-section standards, to organize their data, solve problems, and communicate ideas. When patterns begin to emerge from the compiled data, an understanding of the regional geologic history and setting takes shape. Exploration for petroleum and mineral resources and for porous rock structures to store petroleum products underground depend on this improved understanding of the physical stratigraphic conditions. An understanding of local and regional geology is also important for assessment of the state's major aquifer systems, and helps to provide a better framework for groundwater-resource protection and management. □

SELECTED SURVEY PUBLICATIONS

WATER RESOURCES OF THE OCHEYEDAN-LITTLE SIOUX ALLUVIAL AQUIFER
DNR-Geological Survey Bureau Open-File Report 86-3, 90 pages, by Carol A. Thompson (1986). The geology, hydrology, and water-producing potential of this aquifer were evaluated from the Minnesota border to the Woodbury-Monona County line. Seismic refraction surveys were used to define aquifer geometry. Nitrate, bacteria, and limited pesticide sampling was done on wells and surface waters. Price: $6.00, plus $1.50 post./hand.

WATER RESOURCES OF THE OCHEYEDAN-LITTLE SIOUX ALLUVIAL AQUIFER: DATA REPORT
DNR-Geological Survey Bureau Open-File Report 86-4, 115 pages, by Carol A. Thompson (1986). A compilation of field data collected during investigation of this aquifer. Supplements Open-File Report 86-3. Price: $5.00, plus $1.50 post./hand.

WATER RESOURCES OF THE ROCK RIVER ALLUVIAL AQUIFER
DNR-Geological Survey Bureau Open-File Report 87-1, 109 pages, by Carol A. Thompson (1987). The geology, hydrology, and water-producing potential of this aquifer were evaluated from the Minnesota border to the confluence with the Big Sioux River. Seismic refraction surveys were used to help define aquifer geometry. Nitrate, bacteria, and limited pesticide sampling was done on wells and surface waters. Price: $7.00, plus $1.50 post./hand.

HOLOCENE ALLUVIAL STRATIGRAPHY AND LANDSCAPE DEVELOPMENT IN SOAP CREEK WATERSHED; APPANOOSE, DAVIS, MONROE, AND WAPELLO COUNTIES, IOWA
DNR-Geological Survey Bureau Open-File Report 87-2, 170 pages, by E. Arthur Bettis III and John P. Littke (1987). Detailed investigations of the late Wisconsinan and Holocene alluvial stratigraphic record were conducted to develop a landscape evolution model. Mapping results provide a basis for formulating sampling strategies necessary to evaluate the archeological resource of the area. The sequence of deposits and their chronology is compared to those identified elsewhere in the state and is incorporated into a region-wide framework for evaluating the role of fluvial processes in shaping the archeological record. Price: $6.00, plus $1.00 post./hand.

AN OVERVIEW OF GROUNDWATER QUALITY IN THE SKUNK RIVER BASIN
DNR-Geological Survey Bureau Open-File Report 87-3, 36 pages, by D. Roger Bruner and George R. Hallberg (1987). Geologic and groundwater quality information were reviewed as part of a cooperative agreement with the U.S. Dept. of Agriculture, Soil Conservation Service. A dependence on shallow groundwater sources or surface water makes portions of this basin vulnerable to contamination problems. Trends in the occurrence of nitrate concentrations with depth were examined. Limited copies. Available without charge.

5,000 copies of this publication were produced at a total printing cost of $4,837. Unit cost 97¢.

Courtesy, Field Museum of Natural History

Rare fossils of early land-dwelling vertebrates found in Keokuk County rank high among North American fossil discoveries. This 340-million-year-old amphibian skull (⅓ actual size) shows exceptional preservation.