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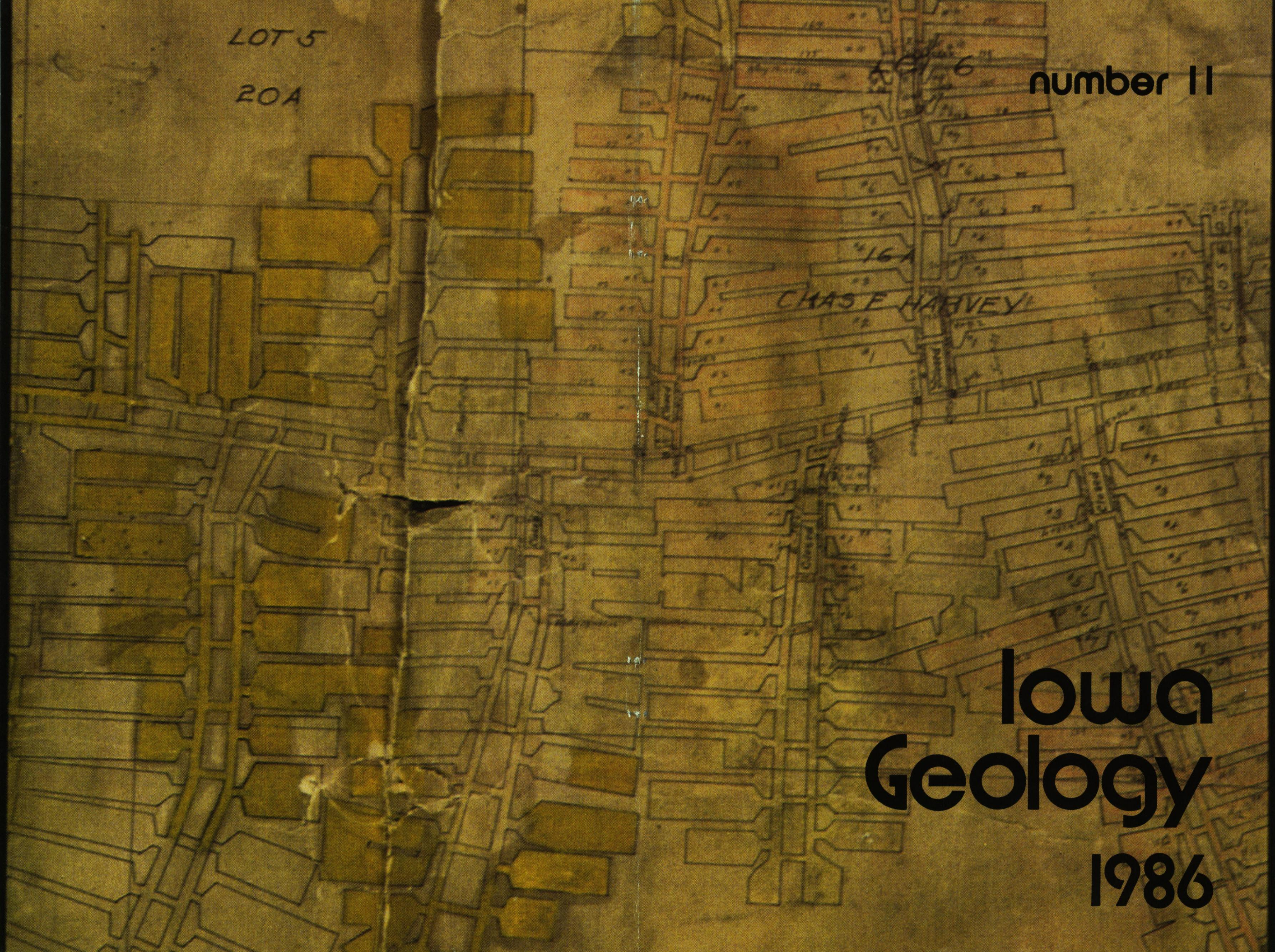

Iowa Geology 1986

Iowa Geological Survey

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Donald L. Koch
State Geologist and Director

Cover:

This original map of the Des Moines Ice and Fuel Co. Mine No. 5 shows the network of rooms, pillars, and passageways left by the underground mining of coal in Clay and Delaware Townships, Polk County, between 1923 and 1928. Scale: 1 inch = approx. 100 feet. Preservation of these maps provides a valuable information base for assessment of the geographic extent of subsidence problems, coal reserve estimates, and general geology.

Cover photo by Paul VanDorpe
Cover design by Patricia Lohmann

Jean C. Prior .... Editor
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Editor's Note: This issue has benefited from the secretarial and proofreading assistance of Lois Bair and Cathy Scherer respectively, as well as the helpful cooperation of the individual authors.

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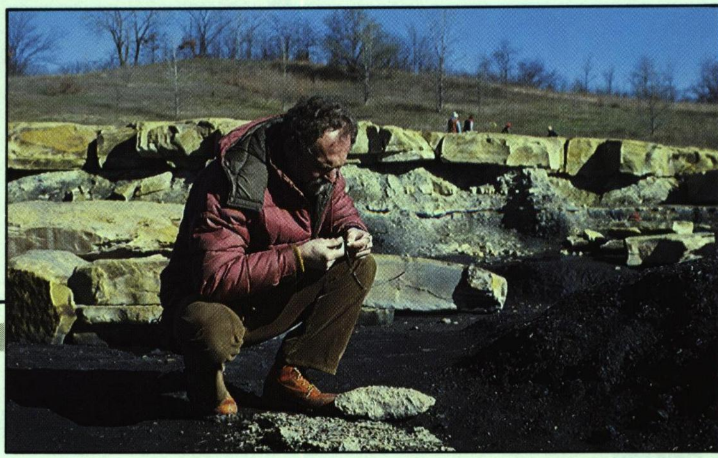

THE DIRECTOR'S VIEWPOINT

This likely will be the last issue of *Iowa Geology* published by the Iowa Geological Survey (IGS) as a separate agency of state government. After two short-lived periods (1855-59 and 1866-69) as a temporary organization, and a continuing (1892-present) agency of the Executive Branch, IGS is to become part of a new Department of Natural Resources (DNR) under plans to reorganize state government. The plans still provide for a Geological Survey and a State Geologist, with the State Geologist being appointed by the Director of the DNR rather than by the Governor, and for implementation of the DNR effective July 1, 1986.

The new organizational structure doubtless will effect changes in matters of policy and operational procedures. Consequently, it seems appropriate to reflect upon the former role of the IGS as a separate agency of state government, and to highlight some of its key goals and contributions. Additionally, it is appropriate to consider the future role of the Geological Survey as a unit within the new DNR.

Since 1892, the mandated role of IGS has been "to make a complete survey of the natural resources of the state in all their economic and scientific aspects . . . including their richness in mineral contents and their fossils; to investigate the different ores, coals, clays, building stones, peats, mineral oils, natural gases, mineral and artesian waters . . . with particular regard to the value thereof for commercial purposes and their accessibility." Throughout its long period of service, a key goal of IGS has been to assist Iowa's diverse public and private interests by providing reliable natural resources information. Additionally, through effective programs of data collection and interpretation, IGS has produced unbiased evaluations that have effectuated balanced resource development, protection, and management decisions.

IGS has made significant contributions in the areas of economic development, environmental protection, and resource assessment and management. The agency's impact on economic development is overwhelmingly manifested through countless water resources reports that formed the basis for the installation of most of the state's public and industrial water supplies. The siting of underground natural gas and liquid petroleum gas storage facilities would have been impossible without a broad geological data base. Likewise, geologic files provided site-suitability infomation for new commercial/industrial developments, and for sanitary landfills and sewage treatment facilities. The minerals industry and government agencies have been well served in the areas of resource exploration, evaluation, production, and site reclamation.

IGS has been in the forefront of activities related to environmental protection. Early warning assessments of water-contamination potential from hazardous waste sites, such as the first hydrogeologic investigations of the LaBounty and Aidex "Superfund" sites, are exemplary. IGS provided leadership in programs that documented systematic, nonpoint-source contamination of groundwater from agricultural chemicals. The growing threat of groundwater contamination from leaking underground storage tanks was expressed long before actions were taken to mitigate the problem.

The agency's contributions to resource assessment and management likewise are notable. Through its Remote Sensing Laboratory, IGS produced the first landuse map of the state, pioneered new methods for flood-hazard assessment, facilitated statewide color-infrared aerial photographic coverage, and developed methods to assist other agencies in forestry and wildlife management, crop inventory, and soil erosion prediction. IGS developed the first quantitative assessment of the changes caused by the alteration of the Missouri River channel, as an aid to determine the resultant loss of wildlife habitat. The agency has contributed greatly to programs of other agencies on such topics as state water planning, soil surveys, state preserves, and land reclamation. Leadership in the development of a computerized natural resources database has enhanced the development of many of those programs.

The goals and contributions that I have mentioned speak well for the role mandated to IGS in 1892. What will be the future role of the Geological Survey as a unit within the new Department of Natural Resources? Prudent development, management, and conservation of Iowa's geological and other natural resources are vital elements to the state's economic stability and growth. There is a finite limit to the state's geological resources; they are not uniformly distributed as to quantity or quality, and competition for their use will continue. We recognize that sensitive geological environments exist which are vulnerable to contamination from man's activities. The state will continue to need a technically qualified source of information to aid in the development, management, and conservation of its geological resources. The Geological Survey, as a unit of the Department of Natural Resources, is well qualified for that role.

Donald L. Koch

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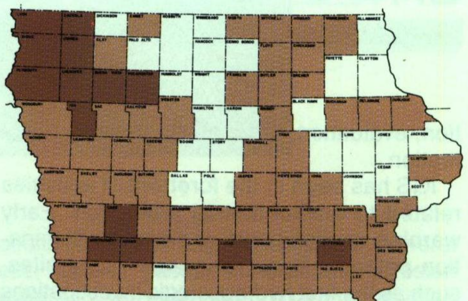
State Geologist and Director

AG-CHEMICALS AND GROUNDWATER QUALITY

George R. Hallberg

The past year brought to our attention numerous headlines concerning water-quality problems. State legislators conducted hearings about water quality and hazardous wastes; state agencies and university scientists held conferences and released new study results; cities and towns made public announcements about water problems; and in Washington, the Congress debated the reauthorization of "Superfund," the Clean Water Act, the Safe Drinking Water Act, and pesticide regulations. A central theme common to each of these events was groundwater — the primary source of drinking water for Iowans, and essentially the only source for rural Iowans.



Water Well Samples exceeding the nitrate contaminant limits

41-70% | 21-40% | less than 20%

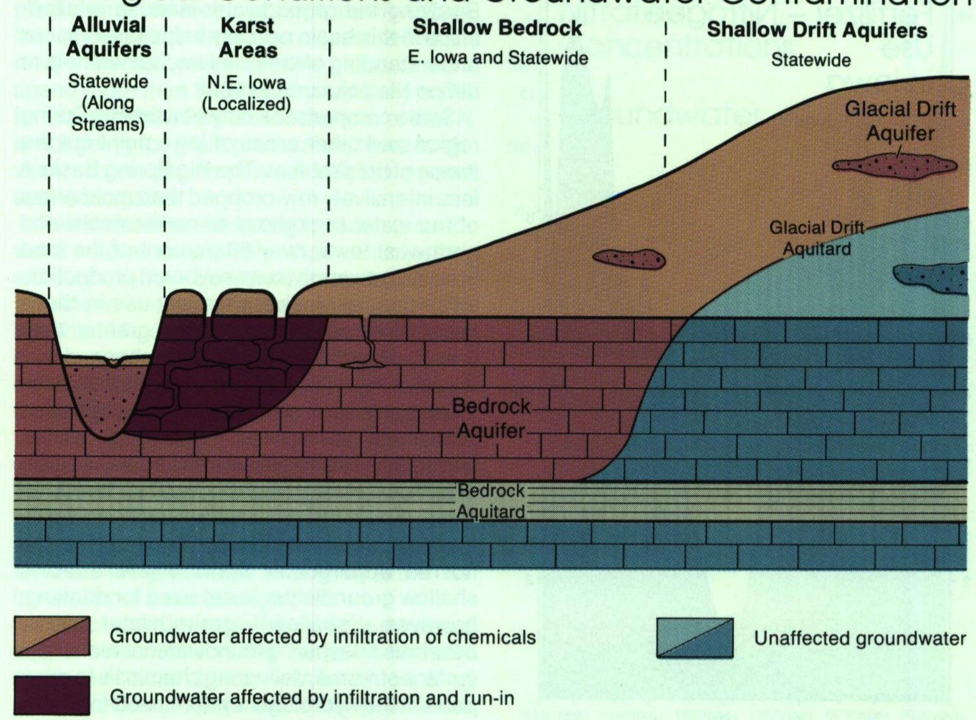
(Data source: R. Splinter, University Hygienic Laboratory; from 13,625 wells less than 100 feet deep)

The contamination of water supplies from hazardous-waste sites and dumps is an important issue, but another aspect of water-quality problems is receiving increased attention throughout the country — the *nonpoint*-source contamination of groundwater which results from the routine use of agricultural chemicals. An important distinction in these issues is that hazardous wastes generally emanate from local identifiable sites, or *point* sources, and though troublesome and very expensive, they often are amenable to remedial clean-up and can be controlled by regulations. Agricultural chemicals, on the other hand, are applied to vast areas of land, and while the contaminants delivered to groundwater are less concentrated, they can affect such broad areas that clean-up is impossible. The only efficient way to deal with these diffuse, nonpoint-source pollution problems is prevention.

Contamination of Iowa's groundwater is occurring via both routes. In any given individual well, many factors can contribute to a contamination problem, such as poor well construction or siting, poor waste-disposal practices, the presence of septic tanks, abandoned wells or drainage wells, and the use of cisterns. Spills or misuse of chemicals also can cause severe contamination problems locally. Studies in Iowa indicate, however, that these individual on-site occurrences play a minor role. Less obvious, but more extensive contamination of aquifers is occurring regionally as the result of the widespread conventional usage of agricultural chemicals.

Ongoing studies in Iowa have become a nationally recognized focal point in understanding the relationship between agriculture and groundwater. For nearly seven years, Iowa's natural resource agencies and university scientists, supported by the U.S. Department of Agriculture, the U.S. Environmental Protection Agency, and the State of Iowa, have

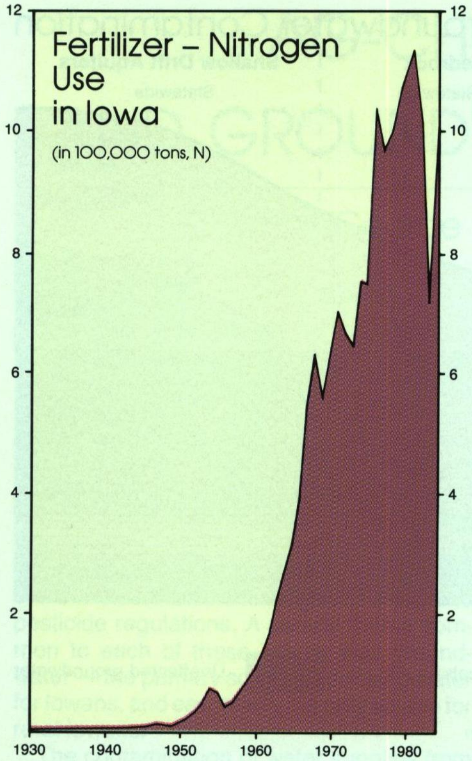
Geological Conditions and Groundwater Contamination



been conducting studies into the occurrence of ag-chemicals in groundwater. These studies show that nitrates and some pesticides are leaching through the soil into shallow groundwater and now are found in many of Iowa's groundwater aquifers. While private farm wells are the most susceptible to problems, public water supplies also are affected. In the 1980s over 40 public water supplies exceeded the maximum contaminant limit for nitrate in drinking water, and many others have had to blend water from different sources in order to meet health standards.

Currently, the distribution of these ag-chemical contaminants is confined to aquifers that occur at a relatively shallow depth, or to the shallow portions of large aquifers, near their recharge areas (see diagram). Contaminated bedrock aquifers are found in karst areas underlain by shallow limestone (primarily northeast Iowa and locally elsewhere), or in areas covered by relatively thin glacial deposits, geologic conditions which are most extensive in eastern Iowa. Alluvial aquifers along river valleys and shallow glacial-drift aquifers in upland positions also are affected. These aquifers occur throughout the state, but are most commonly developed for water supplies in central and western Iowa. In part, this shallow distribution of contaminants is a function of time. Ag-chemicals have been used extensively for only about twenty years. Hence, there has not been enough time for such contaminants to penetrate more deeply into the groundwater system, especially in areas where *aquitards retard* the movement of water and chemicals. Even if chemical usage remains constant, in time, this contamination can, and likely will, become increasingly widespread.

Much of the research, and thus perhaps too



much of the attention to this problem, has been focused in northeast Iowa, particularly the Big Spring Basin. Such contamination, however, clearly is occurring throughout Iowa and the corn belt states. Detailed research continues in the Big Spring Basin, not because of its unique or severe water-quality problems, but because the area affords an excellent opportunity to study groundwater in ways simply not available elsewhere. Nearly 90 percent of the groundwater discharging from the basin comes out at the Big Spring. Therefore, the volume of groundwater moving through the region can be quantitatively measured. Also, the basin's landuse is wholly agricultural, and the results are not complicated by other sources, such as municipal or industrial waste effluents. Furthermore, the groundwater system responds quickly to changes. Groundwater recharge events and subsequent discharge events can be measured and related. Studying the groundwater-landuse relationships in this basin not only helps to refine our understanding of the problem, but will help to define the solutions as well.

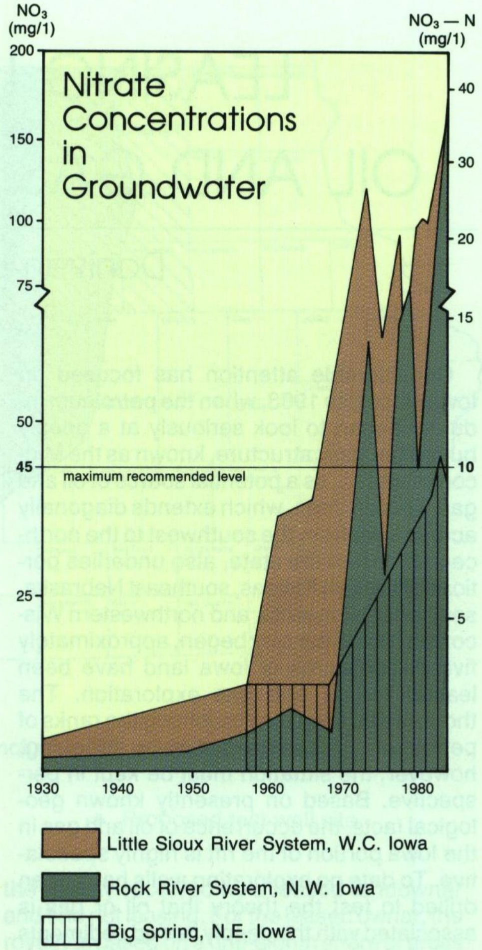
Some comparisons between the Big Spring region and other areas of Iowa point out the scope of the problem. The Big Spring Basin is less intensively row-cropped than most areas of the state. In portions of north-central and northwest Iowa, over 80 percent of the land area is in row-crop (corn-soybean) production. With more extensive chemical use in these areas, water-quality problems greater than those in northeast Iowa have been documented. In any recent year, 60 percent of the state's total land area has been in row-crops with chemicals applied. This figure underscores the meaning of nonpoint source and the magnitude of the potential problem. Studies indicate these land-applied chemicals are leaching to groundwater throughout Iowa. This may not be apparent in areas where affected shallow groundwater is not used for drinking; however, "shallow" groundwater slowly becomes "deeper" groundwater or recharges surface streams, delivering chemicals to other parts of the hydrologic system used for drinking water.

Data from the Big Spring Basin show that nitrates in groundwater have increased in direct proportion to the increased use of nitrogen (N) fertilizers. This trend is seen throughout the state, but in western Iowa the rise in nitrate concentrations in susceptible aquifers appears to be much greater. The map on page 4 summarizes nitrate data for private individual wells compiled by the University Hygienic Laboratory. Statewide, 28 percent of all samples tested exceeded the maximum contaminant limit (45 mg/l NO_3) established for public water supplies. In northwest Iowa, however, 40 to 70 percent of the samples exceeded this limit. Again, it is clear that nitrate contamination, in respect to concentrations, is more prevalent in northwest Iowa than in northeast Iowa. Monitoring of the Big Spring Basin shows that losses of nitrate-nitrogen to the groundwater are equivalent to a minimum of 33 to 50 percent of the N-fertilizers applied. Experiment-farm studies also show that only about 35 percent of the fertilizer nitrogen applied is removed in corn grain production. Such losses constitute an economic, as well as an environmental concern. In Iowa alone, farmers spend more than $400 million annually on N-fertilizers; when 50 percent or more of that N is not going for grain production, there is obvious room for improved efficiency and economic gains.

Pesticides also are being found in groundwater more extensively than anticipated, although in low concentrations. Losses of pesticides into water appear to be generally less than 10 percent. Given the environmental concern with these chemicals, even these losses should be minimized. Prior to the initiation of the studies described here, there were very few analyses run to test for the occurrence of pesticides in groundwater. Data collected by the University Hygienic Laboratory since 1968, however, together with the current studies, suggest that pesticide residues in groundwater are increasing, perhaps analogous to the rise in nitrates of a decade ago.

Public health is the reason for concern about aquifer contamination. The existence and persistence of these chemicals in Iowa's drinking water provide the potential for long-term and widespread exposure. At this time, there are many questions and few answers about the long-term biological implications of the coexistence of nitrates, pesticides, and other chemicals. Some epidemiologic studies suggest patterns of risk, but unfortunately epidemiologic proof often takes a generation or more of exposure. In addition, specific studies designed to examine the risk from farm chemicals have not been done.

Iowa's Big Spring Basin Demonstration Project is an interagency, interdisciplinary program which is developing needed technical and institutional models designed to help resolve these problems. The project will cost $6.8 million; $4.2 million is currently being sought from federal agencies and private foundations. In terms of potential economic efficiency, this figure represents less than one percent of what Iowa farmers spend for ag-chemicals in a single year. While the project has received widespread technical and political support, the funding remains uncertain.



Ag-chemicals have played an important role in the growth of agricultural productivity during the last two decades. As evident on many fronts, we must now become more efficient in our production if we are to restore profitability to agriculture. The judicious and economic use of chemicals can play an important role in those improvements. We must develop holistic approaches to agricultural management, coupling our need for efficient crop production, soil conservation, and surface-water protection, with groundwater protection as well. □

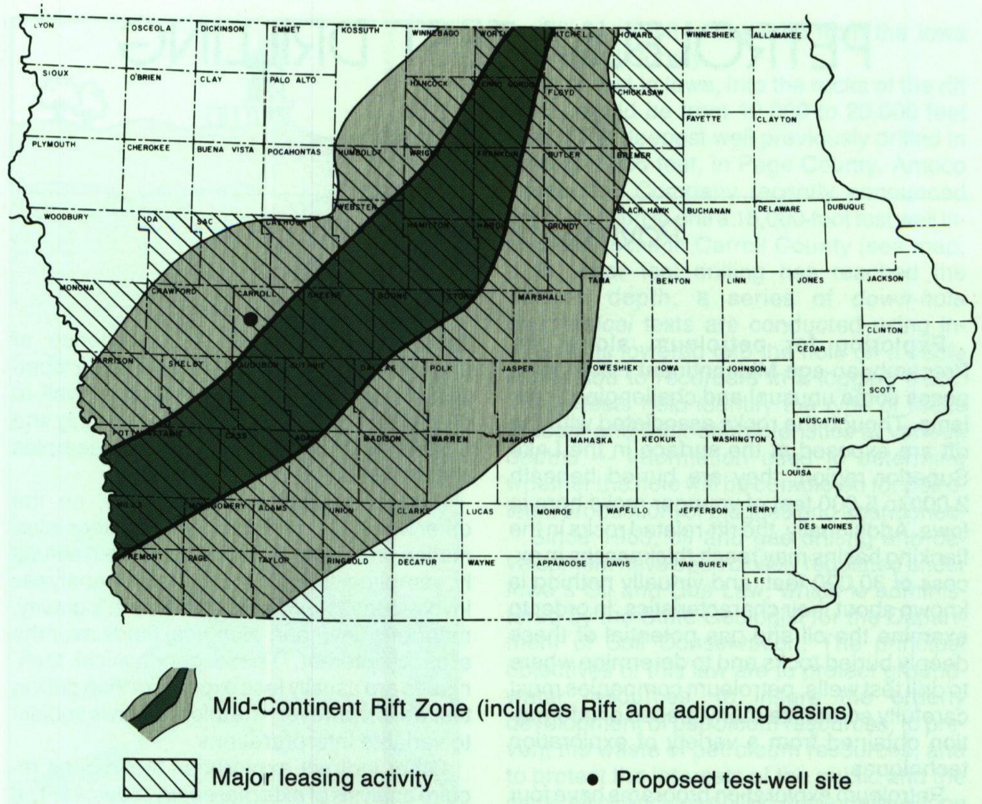
LEASING LAND FOR OIL AND GAS EXPLORATION

Donivan L. Gordon

Considerable attention has focused on Iowa since late 1983, when the petroleum industry began to look seriously at a deeply buried geologic structure, known as the Mid-continent Rift, as a potential source of oil and gas. This rift zone, which extends diagonally across Iowa from the southwest to the north-central part of the state, also underlies portions of eastern Kansas, southeast Nebraska, southeast Minnesota, and northwestern Wisconsin. Since the *play* began, approximately five million acres of Iowa land have been leased for oil and gas exploration. The thought that Iowa may be joining the ranks of petroleum producing states is intriguing; however, the situation must be kept in perspective. Based on presently known geological facts, the occurrence of oil and gas in the Iowa portion of the rift is highly speculative. To date no exploration wells have been drilled to test the theory that oil or gas is associated with the deeply buried sediments associated with the rift. Regardless, interest is intense, and this activity has prompted many questions concerning oil and gas leasing activity in the state.

In discussions there are many references to a standard oil and gas lease — sometimes called a *Producers 88.* There may be some standardization in lease forms or formats, but there is really no single, exclusive standard lease. As a general rule, oil and gas leases are tailored to the requirements of the company (lessee) with respect to access to the leased property and considerations relating to drilling of test wells, developing wells, and transporting crude petroleum or gas. In this regard leases commonly have provisions that allow the building of roads, erecting structures, laying pipelines, and moving fences. A lease may state the lessee's obligations with respect to compensation for crop damage and restoration of the drilling site to its original condition when operations have ceased. State law requires mandatory recording of all oil, gas, or mineral leases of a duration greater than five years with renewals.

The main provisions of an oil and gas lease relate to its *term,* the landowners share of production *(royalty),* and the advanced royalty or *annual rental fee* paid per acre to keep the lease in force. The most common term for leases being negotiated in Iowa appears to be 10 years, and the most common rental fee being offered is $1.00 per acre per year. Unless the lease is a *paid-up lease,* where a one-time fee is paid for the entire term of the lease, the annual rental fee is due on or before the anniversary date of lease, each year, for the term of lease. A lessee can default on this type of lease by not paying the annual rental fee. The only case where annual royalties are paid on paid-up leases is when oil or gas is discovered and, because of economic or other constraints, the well is *shut in* — not developed. For the duration that a well remains shut in, an annual rental fee, usually $1.00 per acre, may be paid in lieu of royalty. On all leases the term of the lease is moot if oil or gas is discovered and producible. In this situation, the lessee is given the right to the leased property as long as oil and/or gas can be produced. Oil production royalties vary considerably from region to region around the nation. Higher royalties are common in areas with proven reserves, while lower royalties are paid in higher risk or unknown areas. The most commonly quoted royalty for Iowa leases has been a one-eighth share (12.5 percent).



Another important issue to consider is the matter of *pooling.* Under the terms of most oil and gas leases, the lessee is given the right to pool production of all lease rights in a given local area. A lessee may also seek to include leased tracts held by others in the locale as well as unleased tracts. Iowa's Oil and Gas Law, found in Chapter 84 of the Iowa Code, provides that this may be done on a voluntary basis. If the desired pooling cannot be achieved voluntarily, however, a majority lease holder can appeal to the Department of Soil Conservation and the State Geologist for a *forced pooling order.* If such a pooling order is issued, other lease tract holders and non-leased tracts are forced to pool their interests under the terms of the order. With forced pooling there could be a significant difference in the royalty received by a leased landowner and one not leasing. For the leased owner, the royalty is based on a one-eighth share of gross production. An owner of non-leased property would also receive a one-eighth share; however, this would be diminished by the individual's proportionate share of the cost of drilling and production. In the case of the leased landowner, all production costs are assumed by the lessee.

Questions concerning Iowa's oil potential from the rift zone can be answered only by a series of deep exploration holes, possibly to depths of 15 to 20,000 feet. Questions as to whether or not a landowner should lease to oil interests is a private business decision and should depend upon the lease offered and on an individual's confidence that the company will fulfill its terms in good faith. □

PETROLEUM TEST DRILLING IN IOWA

Raymond R. Anderson

Exploring for petroleum along the Precambrian-age Midcontinent Rift in Iowa poses some unusual and challenging problems. Though the rocks associated with the rift are exposed at the surface in the Lake Superior region, they are buried beneath 2,000 to 5,000 feet of younger rocks here in Iowa. Additionally, the rift-related rocks in the flanking basins may reach thicknesses in excess of 30,000 feet, and virtually nothing is known about their characteristics. In order to examine the oil and gas potential of these deeply buried rocks and to determine where to drill test wells, petroleum companies must carefully scrutinize many pieces of information obtained from a variety of exploration techniques.

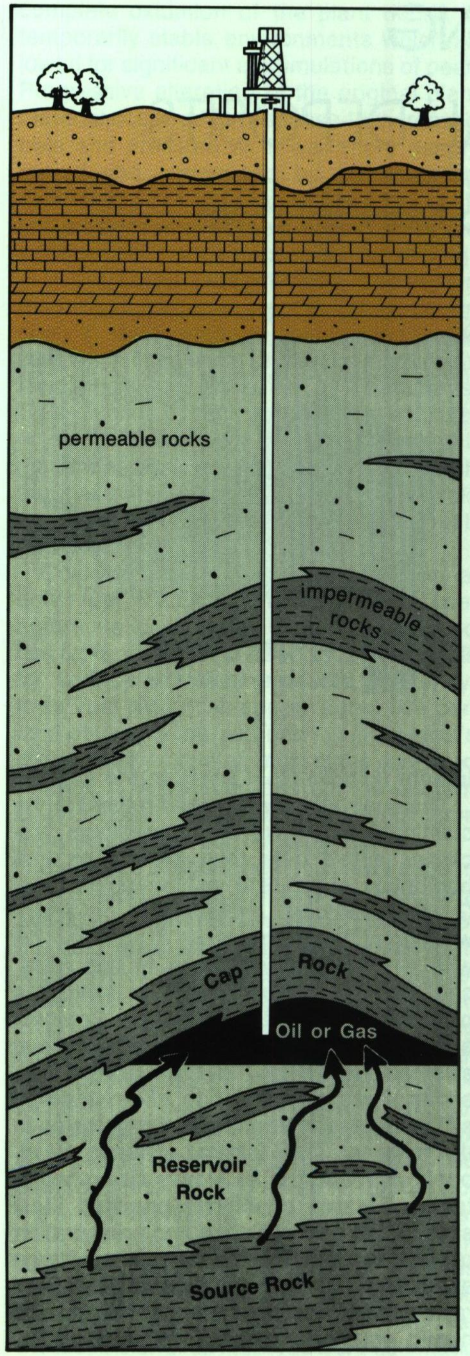
Petroleum exploration programs have four primary goals. They are designed to identify possible *source rocks,* or organic-rich units that could provide the raw material from which petroleum is generated. Secondly, they try to determine the *maturation history* of the source rocks, or if appropriate geological combinations of heat, pressure, time, and migration have occurred. Third, they try to locate *petroleum traps,* or permeable reservoir rocks where petroleum accumulated during migration, confined by an impermeable seal or *cap rock.* Finally decisions are needed on the best locations for test drilling.

The exploration techniques employed to reach these goals along the Midcontinent Rift zone include direct examination of available rock samples. This involves study of known outcrops in the Lake Superior region, as well as available drill cores and cuttings reposited at the Iowa Geological Survey. Rock samples are examined for their porosity, permeability, source-rock potentials, and evidence of petroleum migration. An exploration company also may drill a stratigraphic test well, to obtain rock samples for needed testing and evaluation in areas where no other samples are available.

Indirect exploration techniques, on the other hand, are methods used to gather information on deeply buried rocks without actually sampling them. One series of analyses involves measurements of the earth's gravity, magnetic field, and electrical fields over the area of interest. These geophysical techniques are usually less expensive than drilling test wells; however, the information is subject to variable interpretations.

Other indirect exploration techniques require analysis of external energy sources. The most commonly used is seismic profiling, a technique that utilizes artificially generated seismic waves, with careful recording of the return reflections produced from variations in rock types or structural features beneath the surface. Seismic profiles of the deeply buried rocks of the rift zone in Iowa require a high-energy seismic source. *Vibroseis,* a technique involving a series of large vibrators attached to specially designed trucks, is most frequently utilized (see *Iowa Geology,* Vol. 10). About 2,500 miles of vibroseis data have been collected to date over the Midcontinent Rift in Iowa.

After these exploration phases are complete, geologists evaluate the information and identify the most favorable location to drill an *oil test,* an exploration well to determine the presence of petroleum. After negotiations with land owners to obtain the required oil leases (see p.8), a drilling site is selected, and



a drilling permit is obtained from the Iowa Geological Survey.

An oil test in Iowa, into the rocks of the rift zone, would be from 10,000 to 20,000 feet deep. The deepest well previously drilled in Iowa is 5,305 feet, in Page County. Amoco Production Company recently announced their intention to drill a 15,000-foot test well into these rocks in Carroll County (see map, p. 9). After test drilling has reached the desired depth, a series of *down-hole geophysical* tests are conducted using instruments lowered into the hole on a cable connected to recorders in a logging truck. These tests help identify the type of rocks present and their characteristics at various depths — information used to determine whether the hole will be completed for petroleum production, or plugged and abandoned.

Since 1963, oil and gas drilling and development have been closely regulated under Iowa's Oil and Gas Law, which is administered by the State Geologist for the Department of Soil Conservation. The principal objectives of this law are to protect groundwater resources, to insure the orderly development of petroleum resources, to prevent the waste of petroleum resources, and to protect the interests of the public and the state. All oil and gas drilling in the state is done under permit, and operators must file information relative to their organizational structure and submit a bond to cover any liability associated with site abandonment or test-well plugging. Permit holders are required to follow certain safety procedures in drilling wells, to submit rock samples from wells, to furnish reports on tests performed on wells, to properly abandon non-producing or *dry* wells, and to restore the land surface at the drilling site. The law provides that the bond under which any drilling permit is issued be maintained in force until the permit holder has satisfied all regulatory requirements. In the event of a producible oil or gas discovery, development would proceed under the jurisdiction of the Department of Soil Conservation as advised by the State Geologist. □

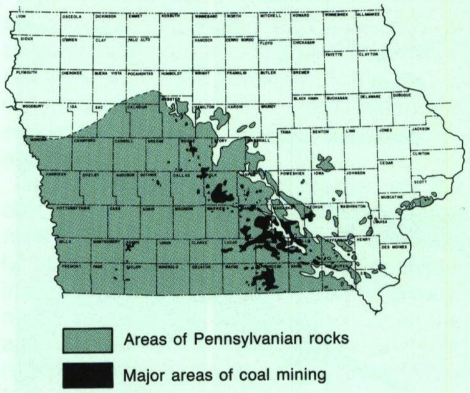
MINING

IOWA'S COAL DEPOSITS

Paul VanDorpe and Mary R. Howes

Coal mining has a long history in Iowa. Initially, coal was dug by hand from surface exposures and hillside outcrops. The state's first official production, 400 tons, was recorded in 1840. As demand grew, mining techniques became more sophisticated; portals and shafts were dug; and immigrant coal miners from Europe and Black miners from the southern states moved into Iowa. The coal industry boomed with the coming of the railroads, and by 1875 annual production topped one million tons. Demand continued to soar, and production peaked at nearly nine million tons in 1917. Shortly afterward, production began to fall and declined steadily after the mid-1930s. Coal production in Iowa since 1975 has averaged slightly more than one-half million tons per year.

The basis of Iowa's coal resources is found within Pennsylvanian-age sedimentary rocks which underlie 35 to 40 percent of the state, primarily in the southern and western counties. This region forms the northernmost extent of the Western Interior Coal Basin which also encompasses portions of Nebraska, Missouri, Kansas, Oklahoma, Arkansas, and Texas. In southwestern Iowa, near the center of the geologic structure known as the Forest City Basin, the Pennsylvanian strata reach their maximum thickness of 1,700 feet. Most of the Pennsylvanian outcrop area in Iowa is situated on the northeastern side of this basin. While this geologic structure confines most of the Pennsylvanian strata to the southern and western parts of the state, a well-known exception is the large outlier of Pennsylvanian rocks along the Mississippi River in Scott and Muscatine Counties. These rocks are an extension of the Eastern



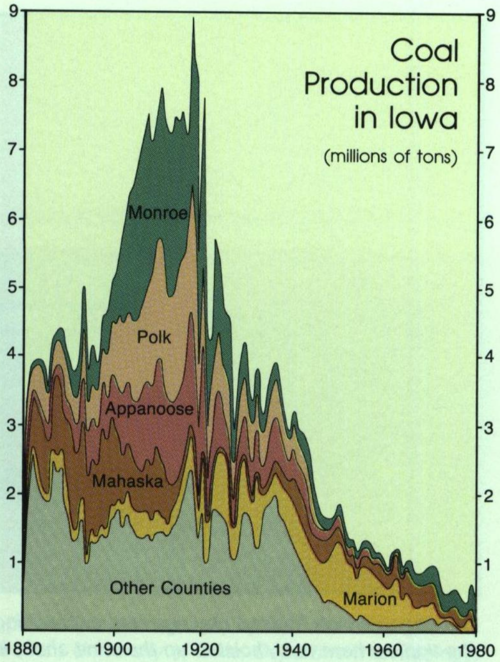
Interior (Illinois) Coal Basin to the east.

The coals which are mined today are the culmination of a variety of geologic processes active over long periods of time beginning about 310 million years ago. Gradual regional subsidence, or downwarping of the earth's crust, in combination with worldwide fluctuations in sea level, caused shallow tropical seas to drown the pre-existing, irregular landscape. Complex environments of shifting, low-relief coastal swamps and deltas, with associated episodes of peat accumulation, alternated with cycles of marine flooding and regression in the midwest. Coal-forming swamps developed in response to slowly rising water tables. Swamp conditions provided ideal sites for the accumulation and preservation of plant material. The transformation of large amounts of vegetation into coal resulted from rapid and abundant plant growth in a hot and humid equatorial climate, followed by incomplete oxidation of the plant debris in temporarily stable environments which allowed for significant accumulations of peat. Progressive alteration of the original plant material occurred in response to increased heat and pressure as it was more deeply buried and compacted by accumulating sediments. Subsequent region-wide uplift and erosion removed the overlying strata and left the coal seams accessible for mining.

During burial, heat promotes a change in the rank of coal from peat to lignite (brown coal) to subbituminous coal to bituminous coal, and ultimately to anthracite (hard coal). Iowa coals are classified as bituminous. Classification by rank indicates the calorific, or heat, value of coal on a moist, mineral-matter-free basis expressed as Btu/lb (British thermal units/ pound). Analyzed Iowa coals range from 10,750 Btu/lb to 13,500 Btu/lb and average 12,040 Btu/lb.

Coal has a variety of uses: conventional boiler fuel, coking coal for metalurgical use, anthracite for smelting, synthetic liquid and gas fuels, and coal tar used as raw materials for various chemical products. Currently, Iowa coal resources supply about five percent of the coal burned each year by Iowa's electric utility industry; most of the coal used in Iowa, however, comes from the western United States, while smaller amounts come from Illinois and surrounding states.

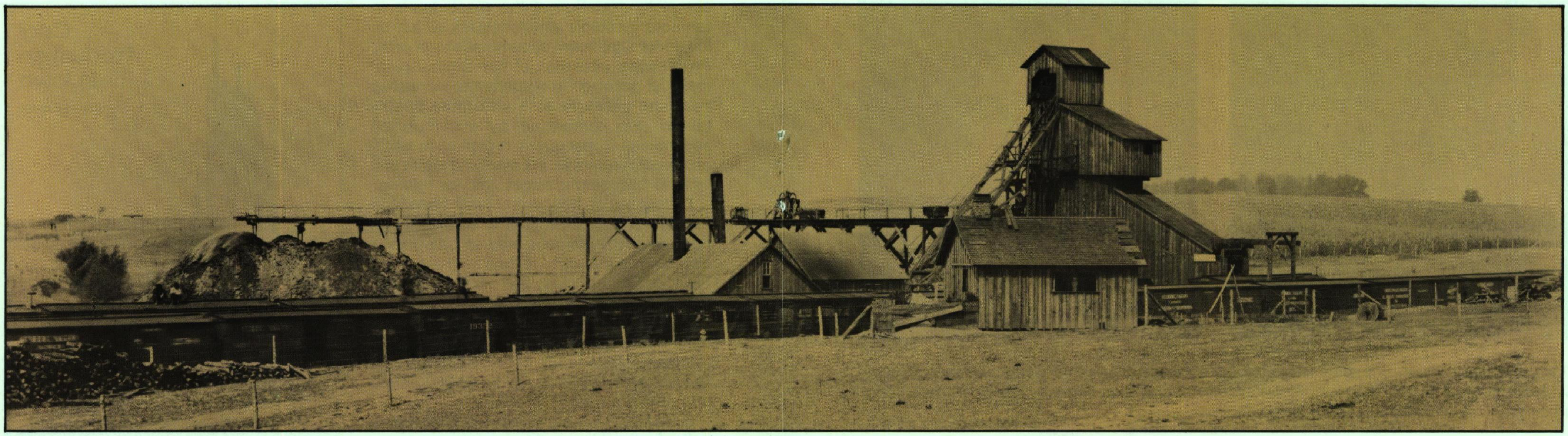
Estimates of coal reserves in Iowa depend on the quality and quantity of geologic data available, so it is not surprising that most of the coal reserves have been estimated in areas where mining has been most active, essentially along the Des Moines River outcrop belt (see map), where the coal-bearing strata are relatively close to the surface. Original reserves for coals greater than 14 inches thick, both measured and inferred, are estimated to be 7,367 million tons in 37 counties, an area of 1.3 million acres (2,056 square miles), or only about 10 percent of the area underlain by Pennsylvanian rocks. In 12 southeastern and south-central counties, 73 percent of the original reserves greater than 28 inches thick are less than 150 feet from the surface. Despite the fact that most of the original reserves were estimated



Five counties have accounted for nearly 70 percent of the state's total coal production.

in areas of intense mining, historic production (1880–1984) from the 10 highest total-production counties accounts for only eight percent of the estimated original reserves and 20 percent of the estimated original reserves less than 150 feet from the surface for coal greater than 28 inches thick. Statewide, since 1840, all mining has accounted for about five percent of the estimated original reserves for coal greater than 14 inches thick.

Labor disputes, health and safety hazards, air pollution, and environmental impacts all have been a part of the history of Iowa's coal industry. Today, the focus is on potential air and water pollution and on concerns about landuse. Most of Iowa's coal mines at one time were underground mines, possibly as many as 6,000 in 38 counties, potentially affecting 80,000 acres. Long-lasting detrimental effects of underground mining include both drainage of acid mine water onto



Structures which housed underground coal-mining operations were a familiar scene in south-central Iowa in the early part of this century when mining activity was at its peak. This photograph, by H. Foster Bain, shows the tipple where coal, hoisted up the mine shaft, is loaded into railroad cars at the Consolidation Mine No. 8, near Given in Mahaska County. (From the Samuel Calvin Collection, University of Iowa, Department of Geology)

surrounding cropland or into surface waters, and subsidence, the process by which the land surface sinks from collapse of the mine roof or failure of the support pillars. Subsidence has caused damage to buildings and property in both rural and urban areas in Iowa. A recent national publication estimates that 3,800 urban acres in Iowa are threatened by mine subsidence. A conservative cost estimate to alleviate subsidence problems, just in these areas, is $114 million. The state's coal regulatory authority, the Department of Soil Conservation (DSC), which administers the Abandoned Mine Lands (AML) program, financially supports IGS studies of potential subsidence-prone areas. These studies locate underground mines by use of existing coal company mine maps (see cover), literature references, published and unpublished historical accounts, and geologic conditions.

When the shift from underground mining to surface strip-mining occurred in the 1940s, topsoil, glacial drift, shale, and other rock material were removed in order to extract the coal. Unfortunately, this overburden remained in large spoil piles where pyrite, an iron-sulfide mineral common in the bedrock, oxidized when exposed to water and oxygen. The weathering products of pyrite include sulfuric acid, which is toxic to wildlife and vegetation. The lack of vegetation contributes to erosion, which in turn exposes fresh pyritic shales to oxidation. Approximately 14,000 acres of abandoned strip-mine lands in Iowa were identified by the Abandoned Mine Lands Inventory of 1980-1981; approximately 9,500 acres of this land were determined to have health, safety, or general welfare problems.

In the middle and late 1970s, Iowa and federal lawmakers required that coal-mined land be restored so that adverse environmental effects are minimized. Mines permitted after the 1977 federal law went into effect must operate so that the land is returned to its original topographic contour and former agricultural productivity. Other regulated aspects of mine operations include surface-water runoff and sedimentation control, as well as protection of local groundwater supplies. Underground mines have a much smaller surface area to restore, but operators must make restitution should subsidence occur over active mining areas. The DSC provides regulatory oversight to active underground and strip mines and administers a portion of the federal coal tax (35 cents/ton surface, 15 cents/ton underground) for reclamation of abandoned mine lands identified as "hazardous." At present, approximately 1,200 acres of Iowa land in this category have been designated for reclamation using these funds. A portion of the federal coal tax also is administered by the federal Soil Conservation Service (SCS) as the Rural Abandoned Mine Program (RAMP), which so far has reclaimed 785 acres in Iowa and is working on another 250 acres.

Despite the problems of working with abandoned mine-land sites in many areas of the country, reclamation efforts in Iowa are relatively straightforward and successful. This results, in part, from the existence of glacial deposits which mantle the coal-bearing strata and can be separated from the rock in the mining process. In the mid-1970s, Iowa State University mined a 37-acre tract of land which was reclaimed by first burying the pyritic shales in the strip pit, covering this with several feet of the glacial drift, and then replacing the topsoil on the surface. This Mahaska County site has been an agricultural research plot through 1985. Agricultural productivity research has demonstrated that this type of reclamation is effective in returning strip-mined land to productive farmland. Since the 1977 federal law, all newly strip-mined lands in Iowa have been reclaimed.

Utilization of Iowa's high-sulfur coals has been tied to regulations designed to protect air quality. Air pollution, mainly by sulfur-dioxide (SO_2), results when the sulfur from sulfur-bearing minerals, mainly pyrite, escapes into the atmosphere when coal is burned. Strict SO_2 emission limits prohibit

Coal Mining in Iowa — Olin, 1965

Mary Howes

The use of small ponies as draft animals to haul coal through low-roofed underground passageways was widespread in turn-of-the-century mines. This method contrasts sharply with the highly mechanized techniques seen in today's surface-mining operations.

the release of excessive amounts of SO_2 from electrical-utility and industrial boilers. Sulfur reduction can be achieved by blending Iowa coal with lower-sulfur coal, and by washing the sulfur-bearing minerals from the coal prior to burning.

Since 1852, when David Dale Owen's first geological reconnaissance of Iowa was published, documentation and study of the geological occurrence and characteristics of the state's coal resources have been a priority with the state's geologists. A.H. Worthen in 1858 discussed the geology of several counties in the lower Des Moines River valley, essentially along the outcrop belt. Considerable portions of the 1870 Annual Report by C.A. White were devoted to the geographic occurrence and geologic relationships of the "Coal Measures Group." In both 1894 (C.R. Keyes) and 1908 (H. Hinds), entire annual-report volumes were devoted to the "Coal Deposits of Iowa." Mining districts were delineated; active mines were located; and the geology, as determined by outcrops, exploration boreholes, wells, and shaft excavations was explained. County geological reports described geological relationships of coal-bearing rocks to other rock units within individual counties. A comprehensive examination of coal reserves by coal bed, township, and county was published in 1964 by E.R. Landis and O.J Van Eck.

In the latter half of the 1970s, the Iowa Geological Survey conducted an extensive drilling program in south-central Iowa to examine in detail the stratigraphic relationships of the coal and associated rocks. Several theses, reports, papers, and publications resulted: the stratigraphy of the major coal-bearing group of rocks was redefined; the geochemistry of the coals was determined; and biostratigraphic correlation techniques using plant and animal fossils were applied to resolve the temporal associations of several rock units, including coal.

IGS maintains interest and expertise in coal-related matters. Studies of coal reserves, coal-seam identification and mapping, abandoned mine and subsidence investigations, creation of a coal mine database system, and assistance to the DSC and the coal industry upon request are all part of the legacy of IGS associations with coal mining in Iowa. □

MINE MAP RESTORATION

Paul VanDorpe and Sharlane Grant*

When the Office of the State Mine Inspector was abolished in the mid-1970s, the Iowa Geological Survey was given approximately 1,400 maps of underground coal mines. These maps, some of which date from the early 1900s, are mostly blueprint, blueline, or original drawings of underground mine workings. They may show outlines of coal excavation relative to surface features, shaft or portal locations, coal thickness, shaft depth, years of operation, and property owners. Over the years, these maps had been stored in disarray and, if not properly cared for, were subject to further deterioration and irrevocable loss.

These underground mine maps are an important historic and scientific resource base. They are particularly valuable for assessing the geographic extent of subsidence problems or potential subsidence events (collapse of the land surface into abandoned mine workings), as well as being useful tools in resource evaluation, coal reserve estimates, and general geology. The Department of Soil Conservation (DSC) and the Iowa State Historical Department (ISHD) are cooperating with IGS to restore and preserve these maps as a primary source of mining, historical, and geologic information. The DSC, as the regulatory authority responsible for Iowa's Abandoned Mine Lands program, provides financial support for restoration of these resource materials. Trained personnel at the ISHD in Iowa City effect the actual map restoration.

Upon delivery of the maps, ISHD personnel inventory each one according to type (blueprint, blueline, oil cloth, tracing paper, paper, paper on cloth, or other) and amount of mending tape present. Each map is then dry-cleaned with an eraser-like abrasive to remove surface dirt and grit (see photo). Next, the map is tested for ink solubility and paper acidity to determine washing conditions. Washing in a pH-controlled water bath completes the cleaning process. Whereas blueprints and bluelines are washed in a slightly acidic bath, the remaining paper maps are deacidified. Then the maps are dried and flattened. Tape removal by a hot knife and organic solvents is performed under a fume hood. Some maps require mending because of excessive tearing or fragmentation. These are mended with long-fibered Japanese tissue. Extremely fragile maps require backing to provide support. Pressing is done, as necessary, to ensure maps remain flat. The final step in the map restoration process is encapsulation in clear polyester film using an ultrasonic welder.

Upon completion, the restored, flattened, and encapsulated maps are returned to IGS for photography, cataloguing, and flat storage in a controlled environment. Photography, with a scale, allows for reproduction without disturbing the newly restored "original." Cataloguing the maps provides important information on the distribution of underground mines. Finally, permanent storage at IGS preserves these valuable maps for future geologists and historians to consult. □

*Conservator, Iowa State Historical Department

Paul VanDorpe

SAYLORVILLE CANYON

E. Arthur Bettis III

The U.S. Army Corps of Engineers, Rock Island District, controls flood-stage flow of the central Des Moines River with a system of two earthen dams (Saylorville and Red Rock) and an intervening levee through the City of Des Moines. Heavy rainfall in the upper Des Moines River Basin during the spring and early summer of 1984 produced extensive flooding in the upper part of the basin and, for the first time, overflow of Saylorville Lake through the emergency spillway at Saylorville Dam just upstream of Des Moines. The overflow event lasted 15 days during late June and early July. Discharge through the unlined, 450-foot wide emergency spillway reached a maximum of approximately 17,000 cubic feet-per-second midway through the discharge event. Erosion of Pennsylvanian and Quaternary deposits along the emergency spillway during the overflow event produced spectacular exposures of these materials.

The emergency spillway consists of a concrete weir with 200 feet of paved chute anchored to underlying, resistant Pennsylvanian sandstone. A thick ledge of sandstone extends down the spillway for some distance and acts as a natural "paved" chute. Farther down the channel, the sandstone gives way to underlying, less-resistant siltstones, coals, shales, and thin limestones of the Middle Pennsylvanian-age Swede Hollow and Floris Formations. During construction of Saylorville Dam, the emergency spillway was graded to a trapezoidal shape. The downstream two-thirds of the spillway was cut into unconsolidated Quaternary deposits which fill a glacial-age valley cut into the Pennsylvanian bedrock. After passing across several different Quaternary deposits, the emergency spillway joins the Des Moines River downstream of the outlet works of Saylorville Dam.

During the 15-day overflow event in 1984, approximately 277,000 cubic yards of material was eroded from the emergency spillway. Erosion was concentrated in the less-resistant Quaternary deposits in the central and downstream portions of the spillway, but significant erosion of the Pennsylvanian strata also occurred where the resistant sandstone was absent.

The resulting exposure of Middle-Pennsylvanian rocks is the best and most accessible outcropping of this stratigraphic interval in Iowa. Approximately 59 feet of vertical section is exposed, including the lower part of the Swede Hollow Formation and upper parts of the underlying Floris Formation. A unique aspect of the exposure is that large areas of horizontal bedding planes are present on the outcrop. This provides a rarely seen view of the third, or horizontal, dimension of the deposits.

The Pennsylvanian rocks exposed here are of particular interest for several reasons. First, the lower part of the Swede Hollow Formation is the oldest widely traceable sequence of rock units in the Pennsylvanian deposits of Iowa. Correlative units extend as far east as Ohio, making it the most laterally continuous sequence in the Pennsylvanian of North America. Secondly, this part of the sequence probably marked the first complete marine inundation of the Iowa area during Pennsylvanian time. Finally, two distinct depositional regimes are represented in this exposure. The lower portion of the Swede Hollow Formation is dominated by marine units, while the underlying upper Floris Formation units are primarily non-marine stream and delta deposits.

Quaternary deposits are found in the central and downstream portions of the emergency spillway. These fill a glacial-age valley cut into the Pennsylvanian rocks. The Quaternary deposits all post-date the last Pre-Illinoian glaciation of the area which occurred around 500,000 years ago.

Fluvial deposits, laid down in a valley by running water, dominate the exposed Quaternary sequence. This is perhaps the most unique aspect of the emergency spillway exposures, since the buried Quaternary sequence in Iowa is usually dominated by upland deposits such as glacial till and loess. One of the emergency spillway's exposed Quaternary deposits, late Wisconsinan alluvium, contains abundant fossil mollusks, as well as plant and insect fossils. This unit was deposited between about 17,000 and 13,500 years ago during advance of the Des Moines Lobe continental glacier into north-central Iowa. Des Moines Lobe glacial till buries the alluvium. Spruce logs and other forest-floor debris are abundant at the contact between the till and the underlying alluvium. These fossils are the remnants of the late-glacial coniferous forest which was overridden by advancing Des Moines Lobe ice. Analysis of these fossils will provide us with a picture of the late-glacial environment as the Des Moines Lobe advanced through north-central Iowa.

While functioning to protect Saylorville Dam from failure, the emergency spillway also has provided geologists and others interested in earth science with a spectacular study area. Further study of the emergency spillway exposures will refine our understanding of both the ancient Pennsylvanian sequence and rather unique portions of the more recent Quaternary sequence. □

Tim Kemmis

Floodwaters sweeping through the emergency spillway at Saylorville Dam left large blocks of sandstone as a lag deposit and exposed spectacular expanses of Pennsylvanian coal, shale, and limestone to view.

ANCIENT AMPHIBIANS DISCOVERED IN IOWA

Robert M. McKay, M. Pat McAdams, Brian J. Witzke, and John R. Bolt

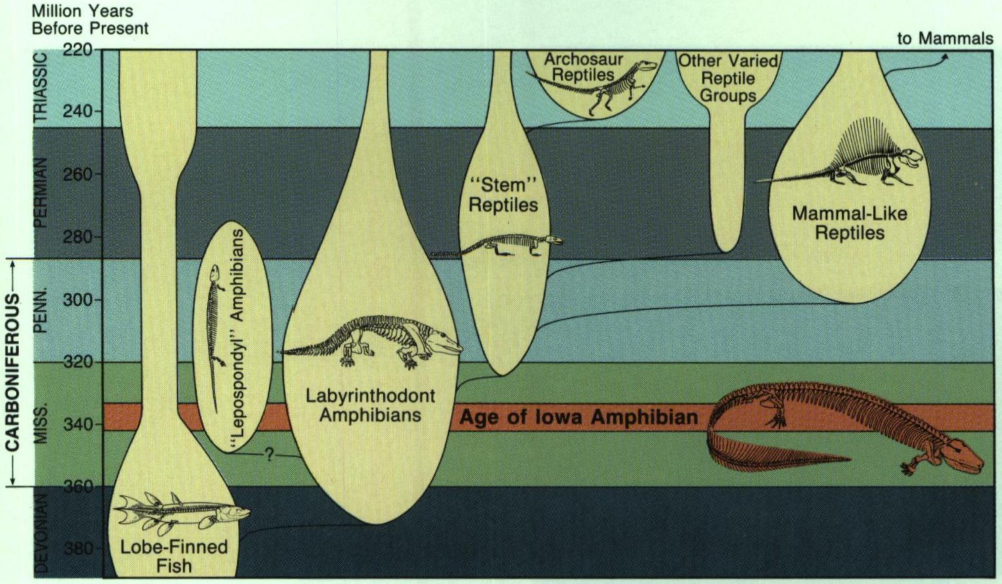
Fossils provide the only direct evidence of ancient life on our planet, and Iowa is richly endowed with an abundance of fossils in our sedimentary rock record. Although Iowa's fossil record has been studied actively for the past 150 years, new discoveries are made every year. Many of the state's fossil faunas and floras are still poorly known, awaiting future detailed description and study. Studies of fossils encompass any of several pursuits: 1) descriptions of fossil forms with interpretations of their biological and evolutionary relationships, 2) the use of fossils as an aid to stratigraphic correlation, and 3) the ecologic and geographic relations between ancient organisms and the environments in which they lived. The most significant fossil discoveries should notably advance our understanding in any of these three categories.

What are the most significant fossil discoveries made in Iowa? A diversity of opinion undoubtedly would be expressed by various geologists in answer to this question. Popular candidates on most lists would include some of the following: 1) exceptionally preserved Mississippian crinoid faunas from LeGrand, Burlington, and Gilmore City; 2) the abundant Devonian faunas from the Cedar Valley and Lime Creek formations; 3) various Pleistocene faunas and floras which provide important insights into glacial and interglacial environments. Microfossil studies in Iowa, too numerous to list here, have made significant contributions to our understanding of temporal and stratigraphic correlations in the region.

A recent fossil discovery in Iowa will certainly rank high on the list of important fossil finds, not only for the state, but for the North American continent as well. A major concentration of fossil amphibian bones in Mississippian strata was discovered in 1985 by the two senior authors of this article. The discovery has sparked considerable enthusiasm among all involved, and detailed study is just getting underway.

Frogs, toads, and salamanders are familiar creatures which represent two of the main groups of living amphibians: four-limbed, vertebrate animals that are at home both in water and on land. All of the living amphibians pass through some sort of "tadpole" stage in individual development, and all have skin that is quite permeable to water, oxygen, and carbon dioxide. Amphibians are thus confined to moist or wet habitats, and the permeable skin is used as a respiratory organ. Modern amphibians, however, are quite different from the early primitive forms which evolved in the Devonian Period and flourished during Carboniferous (Mississippian and Pennsylvanian) time only to become extinct in the late Paleozoic and Triassic. These primitive amphibians deserve special consideration in the study of earth and evolutionary history because they represent the first successful attempt by vertebrate animals to migrate from the aquatic realm and colonize the land.

Amphibians are the most primitive and earliest known tetrapods (four-footed animals), and are the basal stock from which all other land vertebrates, including reptiles, birds, and mammals, have derived. It is generally accepted that amphibians evolved from bony crossopterygian (lobe-finned) fish (see diagram), but the early history and subsequent radiation of early tetrapods during the Carboniferous is still poorly known, principally because of the sparse number of fossil localities and specimens worldwide. In May, 1985, an important new fossil amphibian locality was discovered in a quarry in southeast Iowa. This limestone quarry, in the upper St. Louis Formation, contains a 12 to 20-inch thick bone bed, which has yielded abundant and well-preserved fossil amphibian bone and fish material during preliminary collecting. The quarry is owned by Mr. Jasper Hiemstra, a landowner and farmer in the area. This discovery marks the first known occurrence of Paleozoic amphibians in Iowa.



The evolutionary relationships of early land-living amphibians and reptiles are not well known. The Iowa discovery will add significantly to an otherwise scanty worldwide fossil record.

The bone bed occurs in the middle of a unique sequence of rocks which were deposited in a depression formed within the flat-lying limestones and shales of the upper St. Louis Formation (see photo). The unusual dish-shaped configuration of the deposit led to closer inspection and to discovery of the fossils. The basal half of the deposit consists of angular to rounded blocks and boulders of St. Louis limestone in a shale matrix containing scattered bone. Overlying this is the bone bed, a semi-continuous to lenticular, bone-rich limestone conglomerate with thin interlayered shales, also rich in bone. Above the bone bed is a sequence of bedded limestones and minor shales containing fish remains, ostracodes and snails, but lacking fossils suggestive of normal marine conditions. At the edge of the depression, these limestones overlap and rest on top of the St. Louis and represent the top of the rock sequence in the quarry. Pleistocene glacial till overlies the rock in the quarry.

The significance of the discovery lies not only in the apparent abundance of very rare fossil amphibians, but also that the deposit is of probable Mississippian age. Most fossil amphibians have been found in rocks of younger Pennsylvanian or Permian age, while only a dozen localities worldwide contain Mississippian specimens, most of these from the British Isles, and two from North America. The Iowa amphibians, though younger than the oldest known amphibians from the Devonian of East Greenland and Australia, are probably older than other Mississippian finds in North America. The an-

Bob McKay

Abundant Mississippian-age amphibian bone was discovered within this unusually shaped limestone and shale-filled depression exposed in a quarry in southeastern Iowa.

tiquity of the Iowa site is important because primitive representatives of early amphibian groups might be present, and it is much closer in time to the important evolutionary transition between fish and amphibians. The Iowa site provides important fossil evidence from a portion of the Mississippian previously lacking tetrapod fossils. As such, the Iowa discovery helps fill in part of a long gap in the fossil record of ancient amphibians and potentially will provide significant insights into the evolution of the early tetrapods. Discovery of this site in Iowa, with its significant quantities of well-preserved fossil amphibian material, is a major paleontological event in the scientific quest to track the evolution of land-living vertebrates. This locality promises to be an unusually revealing "window on the past."

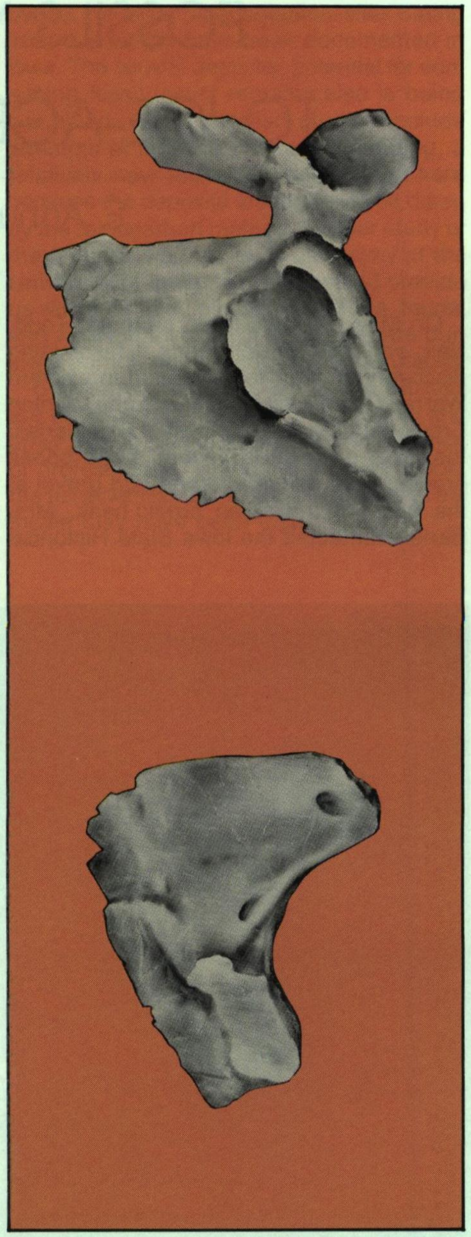
Preliminary collections from the bone bed include disarticulated and semi-articulated cranial and post-cranial remains. These include: jaws with teeth, pelvic girdles, shoulder girdle elements, limb bones (femur, humerus, ulna, radius, and smaller carpal and phalangeal elements), vertebrae and ribs (see illustration of fossils). Bone from the shale is typically compressed and flattened, while bone in the conglomerate has retained its original shape. Although the limited initial collection has not been fully prepared or described, it is apparent that bones of several amphibians of varying size are present. The largest pelvis probably came from an individual whose total length exceeded six feet. Further study is needed to confirm whether more than one species of amphibian is represented in the collection.

Many of the bones clearly represent amphibians from the subclass Labyrinthodontia, an important group of primitive amphibians. Described remains of early labyrinthodonts from the Devonian of Greenland and the Carboniferous of Scotland illustrate the skeletal anatomy of similar primitive amphibians. Early amphibians superficially resembled salamanders; they possessed elongate bodies, short limbs, and required water in which to lay their non-amniotic eggs to complete their reproductive cycle. Many primitive amphibians were quite large, however, some measuring six to ten feet in length. They were covered with bony scales, and the size and shape of their teeth demonstrate that they were voracious predators whose diet probably consisted mainly of fish. The environment in which they thrived probably was one of shallow, fresh to brackish-water pools, ponds, and streams in lowlands marginal to the sea.

Why did such a concentration of bones occur at the Iowa amphibian site? And what forms of amphibians are represented? We are presently working to answer these questions and others. Based upon our work last summer, we know that the bone bed and associated sediments were deposited during a time interval after the regression of the St. Louis seas, but prior to the transgression of the seas which deposited the younger Pella Formation. During this time period an unconformity, or surface of erosion, was developed upon the St. Louis limestones. Formation of karst from the dissolution of limestones and perhaps deeper evaporite (gypsum) beds, plus erosion by flowing water sculpted subtle relief into an otherwise flat landscape. Streams and water-filled depressions on this surface were probably excellent locations for amphibians to feed and reproduce. More importantly though, these same depressions served as sites where skeletons and bones would be deposited, buried, and preserved from the destructive effects of weathering and decay.

To fully understand what type of amphibians, fish, and perhaps other animals are present, as well as the subtleties of their habitat and mode of preservation, more investigative work is needed. The Field Museum of Natural History in Chicago has taken an active interest in the site, and this summer we jointly begin a systematic excavation of the deposit, funded by a research grant from the National Geographic Society of Washington, D.C. □

Editor's Note: Pat McAdams is Instructor of Earth Science at William Penn College in Oskaloosa, Iowa. John Bolt is Chairman of the Department of Geology and Associate Curator of Fossil Reptiles and Amphibians at the Field Museum of Natural History in Chicago, Illinois.



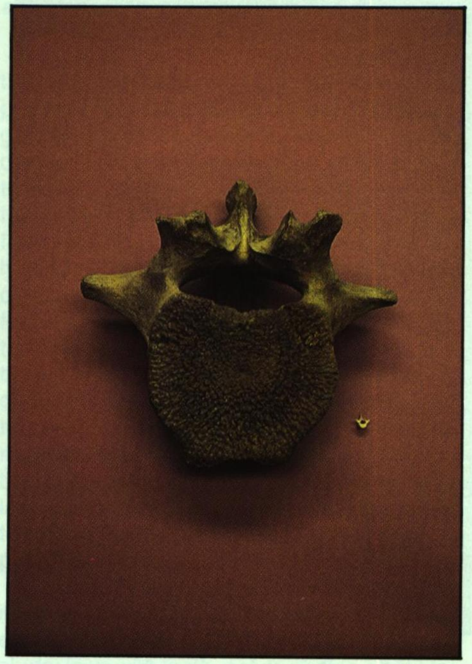
Zbignier — Chicago Field Museum

Amphibian fossils include a pelvic girdle, top, and a scapulocoracoid (a bone in the shoulder girdle), bottom. Illustrations are 54% natural size.

FOSSILS YIELD KEY TO ICE-AGE ECOLOGY

E. Arthur Bettis III

On May 27, 1985 three brothers, Todd, Neil, and Kyle Bartelt made a fascinating discovery on their father's farm in western Warren County. While fishing along Clanton Creek, northeast of the town of St. Charles, the boys discovered several large bones eroding from a layer of sand and gravel at the base of the steep creek bank. Mrs. Bartelt contacted the Iowa State Historical Department and the Iowa Geological Survey, and personnel were sent to examine the bones and the deposits in which they were found.



Kay Irelan

A vertebra from the glacial-age proboscidian is compared in size to the vertebra of a skunk.

The size and shape of the bones indicated that they belonged to a proboscidian, the order of mammals which includes modern elephants, as well as extinct glacial-age mastodons and mammoths. To date, no teeth have been found at the site. Teeth are the most diagnostic element of the skeleton of proboscidians, allowing paleontologists to readily distinguish between mammoths, which were grazers, and mastodons, which were browsers. Further complicating the identification of the Clanton Creek proboscidian is the fact that the bones are those of a juvenile, and therefore had not attained their full size at the time of the animal's death.

Interest in the discovery of the bones is matched, if not exceeded, by the interesting sequence of deposits within the creek bank exposure. These deposits compose an alluvial terrace and represent materials deposited by an ancestor of the modern Clanton Creek. Pennsylvanian-age shale is exposed at creek level, just below the bone-bearing gravel bed. The much younger alluvial deposit comprising the terrace grades upward from the stream gravels into a complex of finer-grained overbank (flood) deposits. Developed in the top of the alluvial sequence is a thick paleosol or ''ancient soil'' known as the Sangamon Soil, regarded as having developed between 80,000 and 120,000 years ago during the Sangamon Interglacial period. This buried soil was distorted and disturbed by permafrost which resulted from intense glacial cold, between about 17,000 and 20,000 years ago, during the height of the last continental glaciation of North America. The paleosol and alluvium, in turn, are mantled with Wisconsinan loess (wind-blown silt) which was deposited across ice-free portions of the Iowa landscape between about 21,000 and 12,000 years ago. During the last 11,000 years, the modern soil developed in the upper surface of the loess, as Clanton Creek downcut and eroded into the old terrace, exposing the deposits containing the proboscidian remains.

The Clanton Creek site promises to be one of the premier paleoenvironmental localities in Iowa. This is the oldest stratigraphically documented proboscidian occurrence in Iowa. In addition, the site contains a well-preserved fossil pollen and plant macrofossil assemblage dating from the last interglacial period. No other paleobotanical sites dating from this period have been documented in Iowa. The alluvial deposits' potential for containing fossil insect remains also is being examined. Other detailed studies include attempts at thermoluminescence dating, a relatively new technique being used here because the deposits are too old to be dated by the radiocarbon method. Further study of the proboscidian bones is underway at the University of Iowa. This site should provide us with a detailed picture of the flora, fauna, and valley landscape of southern Iowa during a portion of the Sangamon Interglacial.

Concerned citizens such as the Bartelts are to be commended for bringing this and other geological discoveries to the attention of professionals. Without their notification, the full scientific and interpretive value of the locale may have been lost. □

Keith Mann

A field crew excavates the Warren County fossil site. The sequence of deposits exposed in the creek bank where the bones were found are carefully measured, described, and sampled for further study.

GEOLOGICAL COMPUTING

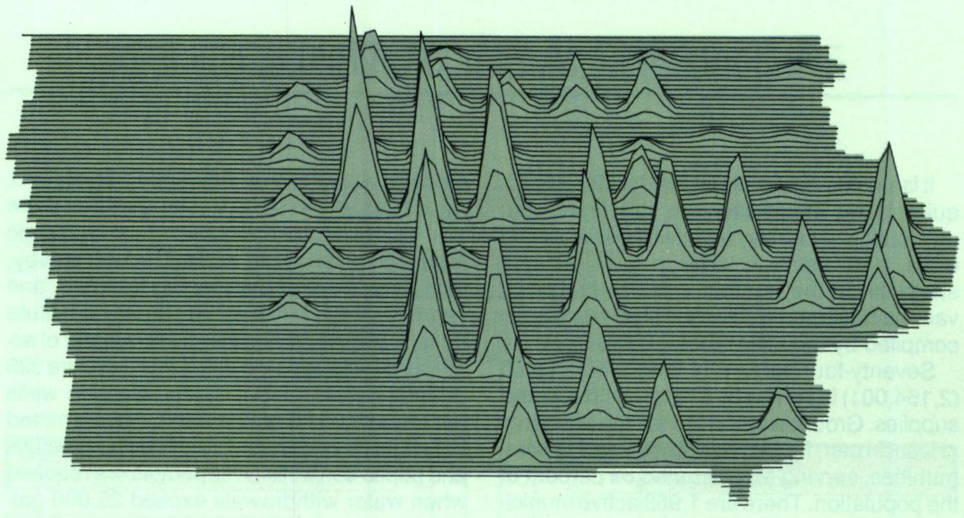
Richard L. Talcott and D. Roger Bruner

Computer data processing and display help to manage, interpret, and communicate information from the voluminous geologic and groundwater files at the Iowa Geological Survey. Basic data from these files are used by our geologists and hydrologists to construct maps of the vast and varied unseen region that underlies Iowa — from the surficial sands, gravels, loess, and glacial tills to the mile-deep Pre-Cambrian basement rocks. Within many of these strata are resources of economic value to the state.

Water is one economic resource of particular concern to Iowans as well as to natural resource planners. Information on Iowa's subsurface geologic and hydrologic characteristics, combined with records of individual water-well performance over the years, can be analyzed to further our understanding of the state's groundwater resources. IGS has over 12,000 computerized stratigraphic records from which to estimate the average thickness of subsurface aquifers, or water-bearing formations. Some 13,000 water-quality records also are available for data on specific groundwater sources, and we have construction and geohydrologic detail for almost 6,000 existing water wells. Recently, at the request of the Department of Water, Air and Waste Management, we searched through our database to prepare an estimate on the state's reserves of groundwater. The process we followed, through one phase of this project, exemplifies the role of the computer as a valuable tool for research, and also demonstrates the need for professional oversight as data are selected for use and results are interpreted.

First we wanted to determine how much reserve potable (drinkable) water is available in the state from confined, or artesian, underground sources. One way to express this amount is to calculate how much water can be pumped before the level in wells falls below the elevation of the top of the aquifer, assuming that withdrawals are evenly distributed. When that threshold is passed, water actually is being "mined," or withdrawn from the aquifer more rapidly than it is replenished. Calculation of this reserve supply must take into consideration the aquifer's storage coefficient (a measure of the amount of water that could be withdrawn from a given amount of space within the geologic unit), the water-level elevation above the aquifer top, and the surface area of the aquifer.

Three water-bearing stratigraphic packages were selected which represent regional sources of groundwater in Iowa: the Silurian-Devonian, Mississippian, and Cambrian-Ordovician aquifer systems. They were selected because they generally provide acceptable water yield and quality and generally are unconnected to one another hydraulically. Geologic maps were consulted to determine which counties contained the major aquifer systems. In each county selected, for each confined aquifer with potable water, the computer calculated the average height of the water level above the aquifer top. This distance is referred to as the *artesian head,* and using this figure, we were able to estimate the volume of reserve confined water within each county using the general formula: Artesian Head × Storage Coefficient × Area = Volume of Reserve. Since there were between five and fifty data locations for each of the three aquifers in any given county, this calculation was one task we were happy to let the computer perform.



Computer-generated graphics visually summarize geologic data. This graph illustrates variations in the reserve supply of drinkable water from artesian bedrock sources across the state.

A three-dimensional graph (see diagram) was constructed to illustrate the variation in reserve supply of potable artesian water across the state. It tends to exaggerate actual differences. The vertical dimension of the graph represents the relative abundance of water from confined bedrock sources. Although the county outlines are not visible, the data were averaged by county and then interpolated, forming the curved, continuous surface. The range of values represented is from 500 acre-feet in Dubuque County, to more than 140,000 acre-feet in Webster County. An acre-foot of water typically serves 9 people for a year.

This graph depicts only confined bedrock sources of potable water. There are areas of the state, especially in the southwest, that rely more heavily on surface water and on alluvial or river valley sources. If these were accounted for in the graph, it would show a greater supply throughout Iowa. Also, the graph shows no potable artesian water stored in the western third of Iowa. Southwest Iowa actually has large volumes of water in artesian storage; however, quality falls short of the standards for drinking water. Northwest Iowa also has artesian water in the Dakota aquifer, some of which is potable. Difficulties in differentiating sand units in well sample cuttings from this area led to some data uncertainties for the Dakota aquifer, so this system was not portrayed. Northeast and part of southeast Iowa also show areas of little or no artesian storage. In these areas the uppermost bedrock units yield large quantities of good quality water from unconfined (non-artesian) storage. The deeper artesian aquifers generally remain underutilized, and thus data about them do not appear in our files. Taking these exceptions into account, one may visualize from the graph that adequate supplies of potable water have had significant effects on human settlement and development patterns in Iowa.

Iowa's natural resource agencies need to know how much water of what quality will be available for the state in the future. The computer, combined with the professional judgments of researchers, plays an important role in preparing this information from data on water quality, stratigraphy, and hydrologic characteristics. □

WATER WELL STATISTICS

It is increasingly important in the 1980s to acquire basic information on the types and distribution of existing water wells, abandoned wells, and drainage wells in Iowa. Recent statistics on the number and distribution of various classes of wells in the state have been compiled by the Iowa Geological Survey.

Seventy-four percent of Iowa's population (2,154,001) is served by 812 municipal water-supplies. Groundwater is the source of supply, at least in part, for 94 percent of these 812 communities, serving an estimated 63 percent of the population. There are 1,958 active municipal wells. Eleven percent of the Iowa population is served by municipal water-supplies which are dependent totally on surface water. The remaining rural population is either self-supplied or dependent on rural water systems. Twenty-two of the 30 rural water systems rely on groundwater.

Results from a 1983-1984 statewide well-identification program, mandated by the 69th General Assembly of the State Legislature, have been analyzed. It is estimated that there are approximately 223,590 rural domestic (household/livestock) wells. The well survey, with 41 percent of the mailing returned, and estimated from census statistics to constitute about a 60 percent sample of the number of active rural wells, also indicates that there are 328 drainage wells, about 1,475 irrigation wells (although 2,052 have permits), 446 permitted industrial wells, and 443 permitted commercial and public-use wells. Well permits are required when water withdrawals exceed 25,000 gallons per day.

Approximately 36,300 abandoned wells are estimated to exist, or one for every six active domestic wells. The largest concentrations of abandoned wells reported occur in south-central and western Iowa, areas which, historically, have been deficient in reliable ground-water supplies. □

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