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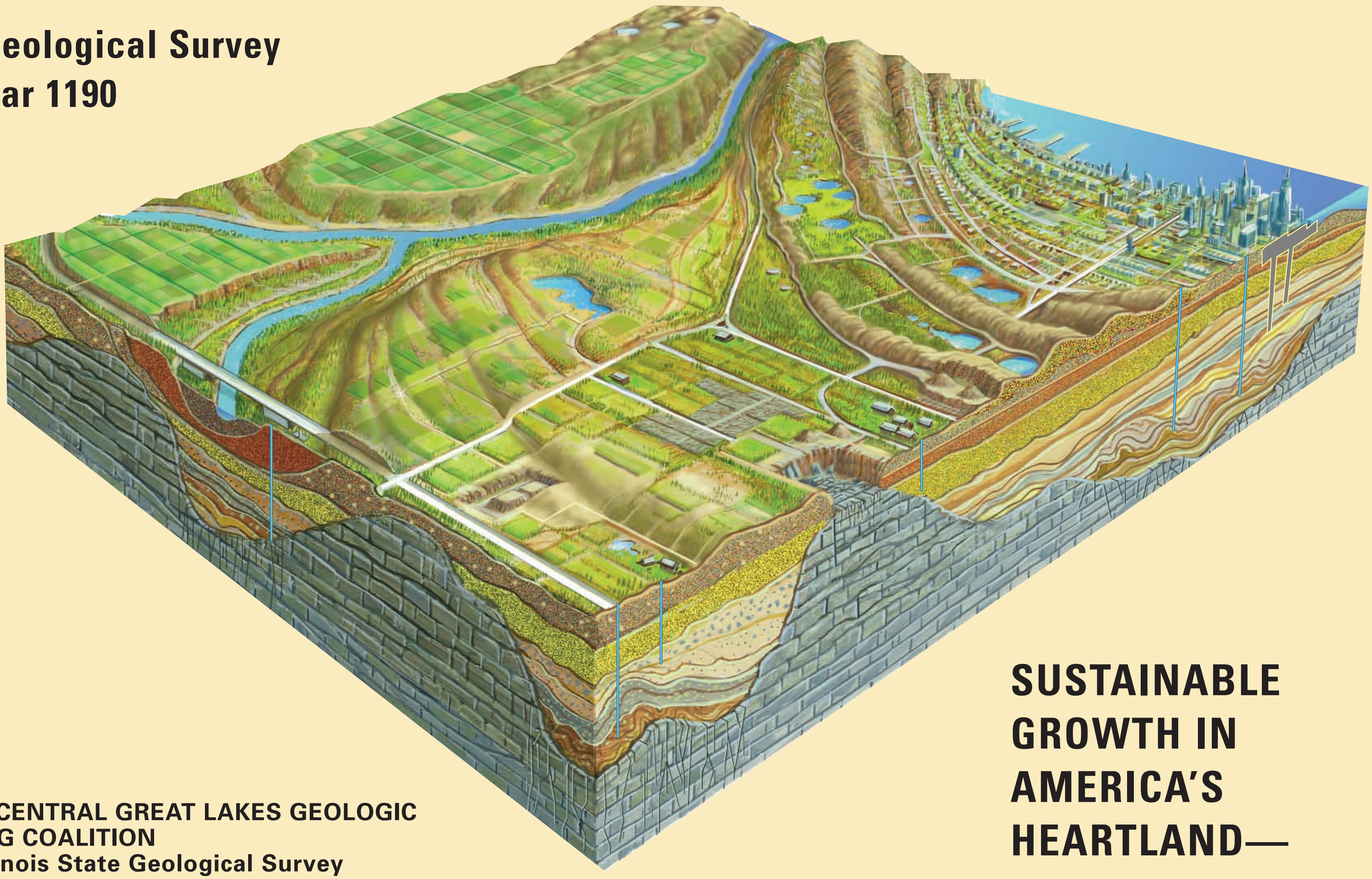

SUSTAINABLE GROWTH IN AMERICA'S HEARTLAND—
3-D GEOLOGIC MAPS AS THE FOUNDATION

BY THE CENTRAL GREAT LAKES GEOLOGIC MAPPING COALITION
Illinois State Geological Survey
Indiana Geological Survey
Michigan Geological Survey Division
Ohio Division of Geological Survey
U.S. Geological Survey

The geologic materials at the Earth's surface in the Central Great Lakes region are the legacy of the ice age. Throughout the region, these materials (gravel, sand, silt, clay, and mud)—

- Are the parent materials of today's agricultural soils
- Are the construction materials we use for buildings and highways
- Are where we dispose of our trash
- Contain the aquifers that supply water to our homes, businesses, and industry
- Provide the habitat for wildlife
- Support the timber and fisheries industries
- Support the environment that we use for recreation

Cover. This block diagram is a generalized representation of surface land uses and underlying deposits in Illinois, Indiana, Michigan, and Ohio. The relatively flat farmland plains and rolling hills conceal a complex mix of glacial deposits stacked above ancient rocky hills and valleys like a pile of rumpled patchwork quilts. During the last 1.8 million years, each glacial advance and retreat modified the previous landscape and deposited new layers of clay, silt, sand, gravel, and till, capped by soil. The thickness of the glacial deposits ranges from a few inches to more than 1,300 feet. Diagram by J.M. Evans.

U.S. Department of the Interior
U.S. Geological Survey

Sustainable Growth in America's Heartland—3-D Geologic Maps as the Foundation

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U.S. GEOLOGICAL SURVEY CIRCULAR 1190

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
CHARLES G. GROAT, Director

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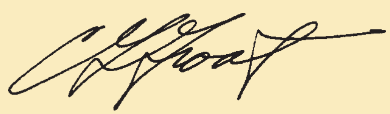
FOREWORD

I am especially pleased to present this Circular describing the Central Great Lakes Geologic Mapping Coalition, because the Coalition represents several important new directions for the U.S. Geological Survey. The plans developed by the Coalition provide a new model for State-Federal collaboration in research, information delivery, and outreach, as well as a most welcome opportunity to work more closely with the various information-user communities. These are activities that I will foster within the U.S. Geological Survey during my tenure as Director, acknowledging the many benefits that come from interacting closely with our customers and the State Geological Surveys, who will be our principal partners in this enterprise. The scope of this activity is such that no single agency can go it alone. Only by actively sharing and combining our resources can we hope to achieve the worthy goals set forth by the Coalition. Although this Circular deals primarily with the geologic foundation for sustainable growth, the program it describes will also serve as the cornerstone in a new integrated science effort that will focus all of the capabilities of the USGS (biology, geography, geology, and hydrology) to address societal needs in the Central Great Lakes region.



Charles G. Groat, Director

Some explanations and definitions . . .

Surficial materials include all unconsolidated (loose, not solid) geologic materials overlying hard bedrock. In the Great Lakes region, most surficial materials were deposited by glaciers or by meltwater in glacial streams or lakes. Windblown deposits (loess) were derived from these glacial materials. Nonglacial materials include stream and lake deposits and materials weathered directly from bedrock. Surficial deposits in the region range in thickness from a few inches to more than 1,300 feet. Ranging from largest to smallest, surficial materials include gravel, sand, silt, and clay. Mud is a mixture of clay, silt, and sand; some mud deposits contain organic matter, which is very fine particles of dead plant debris. Glacial till, a compressed mixture of clay, silt, and sand, with scattered gravel, is very compact and is usually impermeable to water.

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 43).

Glaciers are sheets of ice of two kinds. Valley glaciers form in high mountain ranges and flow downward, carving out distinctive glacial U-shaped valleys. They occur in many of the high mountainous regions of the world today. Continental glaciers are ice sheets that cover large areas and can be over 1 mile thick. Both types leave behind deposits of mixed gravel, sand, silt, and clay. Continental glaciers now are present only in Greenland and Antarctica. During the ice age, glaciers covered vast regions of the Northern Hemisphere; they advanced and retreated over portions of the Midwest several times in the last 1.8 million years. The current ice retreat began over 18,000 years ago. We are probably still in the ice age but are experiencing a warm period when the glaciers have retreated. They will probably advance again. Scientists cannot predict exactly when or why.

Traditional surficial geologic and soils maps depict the distribution of surficial materials in the uppermost few feet of the land. Such maps are based primarily on interpretations of landforms and field examination of materials exposed in shallow excavations, streambanks, or drill holes. Traditional surficial geologic and soils maps are considered to be two-dimensional because they provide information on the areal distribution of surficial materials and not the distribution of surficial materials at depth.

Three-dimensional surficial geologic maps depict the distribution and thickness of surficial materials from the Earth's surface down to and including the top of bedrock, which may be hundreds of feet below. Improved drilling and geophysical methods, together with recent advances in computer technology, make it practical to gather, display, and analyze earth science information in ways never before possible. When the necessary information is obtained, geologists now have the ability to characterize and geometrically depict the 3-D extent of different types of surficial materials at great depths below the surface.

Location of the four Central Great Lakes States. The heavy line shows the southern extent of continental glaciation in the United States during the last ice age (from Soller, 1998).

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Illinois State Geological Survey

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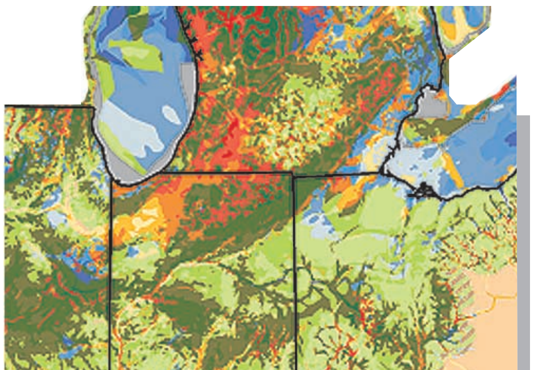
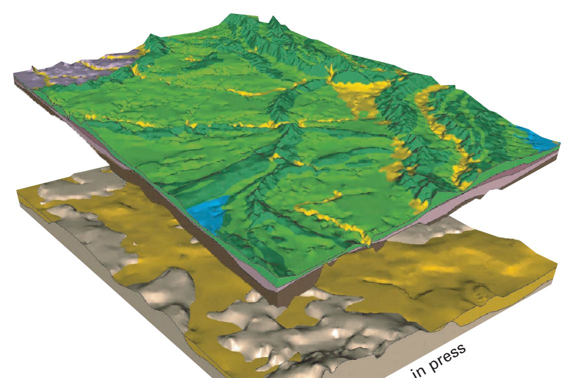


Soller, 1998

U.S. Geological Survey

Illinois State Geological Survey



Soller and others, in press

Illinois, Indiana, Michigan, and Ohio have 18 percent of the Nation's land and 15 percent of the Nation's population. These States contribute—

- Half of the Nation's heavy industry
- Twenty percent of the Nation's total employment
- One-third of the Nation's corn and soybean production
- More than half of the Nation's trade with Canada
- Five of the 25 largest cities in the Nation
- Headquarters for 91 of the Fortune 500 companies

Illinois State Geological Survey

Urban landscape.

Illinois State Geological Survey

Transportation crossroads of America's heartland.

U.S. Natural Resources Conservation Service

Corn Belt agriculture and family farms, a way of life.

SUSTAINABLE GROWTH IN AMERICA'S HEARTLAND—3-D GEOLOGIC MAPS AS THE FOUNDATION

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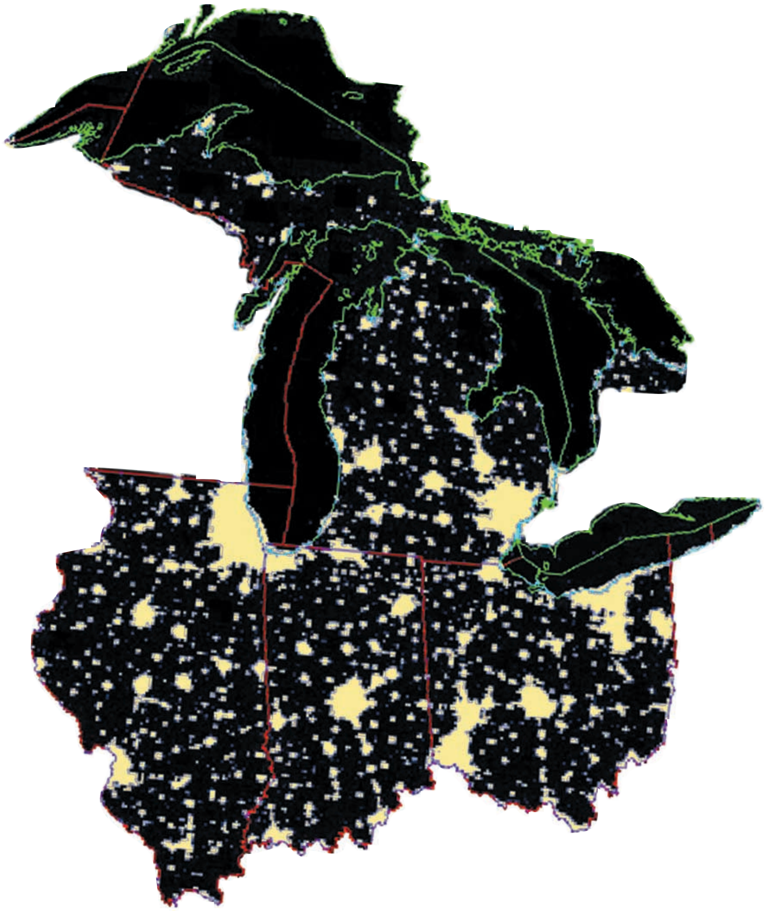


Population patterns revealed by lights at night. Satellite image published with permission of the International Dark-Sky Organization.

INTRODUCTION

The Central Great Lakes States of Illinois, Indiana, Michigan, and Ohio constitute one of the most productive and economically important regions in the country—America's heartland. The agriculture, industry, business, recreation, and ecology of these States are based on a common geologic heritage.

During the last 1.8 million years, glaciers repeatedly advanced and retreated across the region, leaving behind a thick, complex blanket of intermixed layers of mud, clay, silt, sand, and gravel. These glacial deposits contain bountiful resources—rich soils; plentiful ground water; minerals for construction; land for agriculture, development, recreation, and wildlife habitat; and lakes and rivers for recreation and wildlife habitat. These materials are also subject to natural hazards—floods, erosion, landslides, radon, and earthquakes—and manmade problems such as soil, sediment, and water contamination from point and nonpoint sources. Resulting land degradation has impaired and restricted human use and enjoyment of the land and caused degradation and loss of wildlife habitat.

The continued economic growth of the region and the security of its population and environment are related to fundamental issues involving land, water, mineral, and biological resources. Addressing the conflicting demands on these resources without adequate information can result in land-use decisions that are not compatible with sustainable development and a continued high quality of life for future generations. Decisionmakers need knowledge of the glacial deposits—their characteristics, three-dimensional (3-D) distribution, and thickness. To provide this knowledge, a coalition of State and Federal Geological Surveys (Illinois State Geological Survey, Indiana Geological Survey, Michigan Geological Survey Division, Ohio Division of Geological Survey, U.S. Geological Survey) has formed to conduct the necessary studies in these four States to depict the 3-D nature of these glacial and related deposits and to interpret these data in cooperation with the user community for specific societal needs.

REGIONAL SOCIETAL ISSUES REQUIRING EARTH SCIENCE INFORMATION

Ours is a growing society of diverse and competing priorities. Sustainable development can occur only when the needs of industry, agriculture, transportation, housing, and environmental preservation are in balance with the resources of the region. Both public- and private-sector managers face increasingly difficult land-use decisions, yet too often they have insufficient information about the sustaining capabilities of the land, water, and biology to guide these decisions. The following questions are typical of the issues facing decisionmakers.

- Are surface- and ground-water supplies adequate for a growing population and industry?
- Will heavy pumping of industrial or agricultural wells or mine dewatering adversely affect ground-water resources?
- Can subdivisions rely on private wells and septic systems, or will public utilities be necessary? Will rural wells become contaminated?
- Are there sources of construction aggregate near proposed developments, and what are the benefits and costs of open-pit quarries?
- What are the potential short- and long-term risks from land and coastal erosion, flooding, land subsidence, and earthquakes?
- Do the natural compositions of the land and water pose hazards to humans or to existing or new development?
- How can critical wetlands and habitat be maintained or restored?

Questions such as these can be grouped under the following eight societal issues. Less than 2 percent of the Central Great Lakes region has been studied and mapped at the level of detail needed to help resolve these issues.

Illinois State Geological Survey

Competition for the land . . .
- loss of prime farmland
- building over potential sand and gravel sources
- redevelopment of abandoned contaminated industrial lands (brownfields)
- suburban sprawl
- habitat restoration and maintenance

U.S. Geological Survey

Water resources . . .
- aquifer location and extent
- water quality and availability
- vulnerability to contamination
- drought management

U.S. Geological Survey

Construction materials . . .
- location of aggregate deposits
- aggregate quality and quantity
- competition with other beneficial land uses
- land-use compatibility

U.S. Geological Survey

Coastal erosion . . .
- inappropriate development
- harmful side effects of coastal protection structures
- bluff recession and loss of beaches
- loss of property
- loss of wetlands and other habitat

Floods . . .
- property loss
- harmful side effects of attempted flood control
- erosion of prime farmland
- sedimentation

Earthquakes . . .
- potential for infrequent, but very large earthquakes in the Midwest
- risk factors affecting building design
- liquefaction of soils (center feature at right)

Contamination of land and water . . .
- safely siting new waste repositories
- cost-effective and safe remediation of contaminated sites, including 180 Superfund sites
- vulnerability of land and water to contamination

Ecosystem change . . .
- preservation and restoration of wetland habitat and prime recreational areas
- preservation of commercial fisheries and timber resources
- understanding the role of geology in the location and character of ecosystems

Illinois State Geological Survey

U.S. Geological Survey

Illinois State Geological Survey

Illinois State Geological Survey

Insufficient information about earth resources adversely affects economic growth and quality of life. The following are a few instances of where better earth science information in the Central Great Lakes region would have eliminated unnecessary expenditures.

- A cost overrun of $14 million during construction of the Upper Scioto West Interceptor Sewer Project, central Ohio, resulted when a tunnel-boring machine was stopped and delayed by unconsolidated cave-fill materials and buried-valley glacial deposits. Prior geologic mapping, geophysical investigations, and proper understanding of the glacial and preglacial history of the region could have revealed this subsurface condition, allowing engineers to anticipate the problem and avoid delays and increased costs.
- $85 million were spent near Martinsville, Illinois, to find and characterize a site to accept low-level radioactive waste. Geologic mapping would have revealed the presence of aquifers in the area, eliminating it from consideration as a disposal site.
- Over 1.4 million acres in the Central Great Lakes States were converted to urban and suburban land use in the decade from 1982 to 1992, resulting in the loss of prime agricultural land and many sources of sand and gravel for construction.
- The Central Great Lakes States have over 3,600 miles of shoreline along the Great Lakes. Each year residential and commercial properties are damaged or lost to erosion along these shorelines. In addition, habitat necessary for maintaining recreation and sport hunting and fishing is lost or damaged by inappropriate shoreline development. A better understanding of erosion processes and habitat needs should be considered in future land-use planning.

SURFICIAL GEOLOGY IN THE GLACIATED HEARTLAND

The flat landscape of the Nation's heartland is deceiving. Hidden below farmland plains and rolling hills are layers of sediments that blanket ancient rocky hills and valleys. Both the prosperity and resolution of land-use problems of this region depend on our understanding of the 3-D distribution and characteristics of these earth materials.

During the last 1.8 million years, as the climate swung between arctic and temperate conditions, giant ice sheets as much as a mile thick advanced and retreated across the Great Lakes region. Each advance left its mark. Boulders dragged beneath tons of glacial ice pulverized, gouged, and grooved the underlying landscape. Glaciers left behind a mixture of clay, silt, sand, and scattered gravel. When compressed by the great weight of the overlying ice, the mixture became a dense, impermeable material called **glacial till**. Rivers roaring from the fronts of the ice sheets cut new valleys and deposited sand and gravel that make up today's major aquifers and primary supplies of sand and gravel for concrete. Cold, dark lakes formed where ice sheets blocked river valleys, leaving behind deposits of mud. Beneath the warm afternoon sun, floods of muddy water poured into the lakes, depositing layers of clay that are the sources for our bricks and tiles. Much of the region's flat land appears just as the glaciers and old lake shorelines left it—a tabletop made of compact till, smoothed in many areas by wave erosion at the edges of ancient glacial lakes.

Each advance and retreat of the ice left behind a landscape composed of patches of clay, silt, sand, gravel, and till, commonly capped by soil. Each new advance and retreat of the ice modified the previous landscape and deposited new layers of sediment. The result is a complex mix of glacial deposits stacked like a pile of rumpled patchwork quilts ranging from a few inches to more than 1,300 feet in thickness.

Harsh winds blowing off the ice sheet raised clouds of sand and silt from the rivers and drying lake plains. Large sand dunes formed nearby. Dust clouds boiled eastward across the land like the great storms of the Dust Bowl days, depositing layers of silt known as **loess**. Glacial till, loess, and lake-bottom sediments are the sources of the fertile soils of the Nation's Corn Belt.

Understanding the distribution and characteristics of materials in this 3-D puzzle, through geologic mapping, is the key to the continued prosperity and sustainable quality of life of the region. But the appropriate information is scarce and takes time to produce. This is why the five Geological Surveys formed the Central Great Lakes Geologic Mapping Coalition.

Illinois State Geological Survey

Multiple glacial tills and buried soils overlying bedrock.

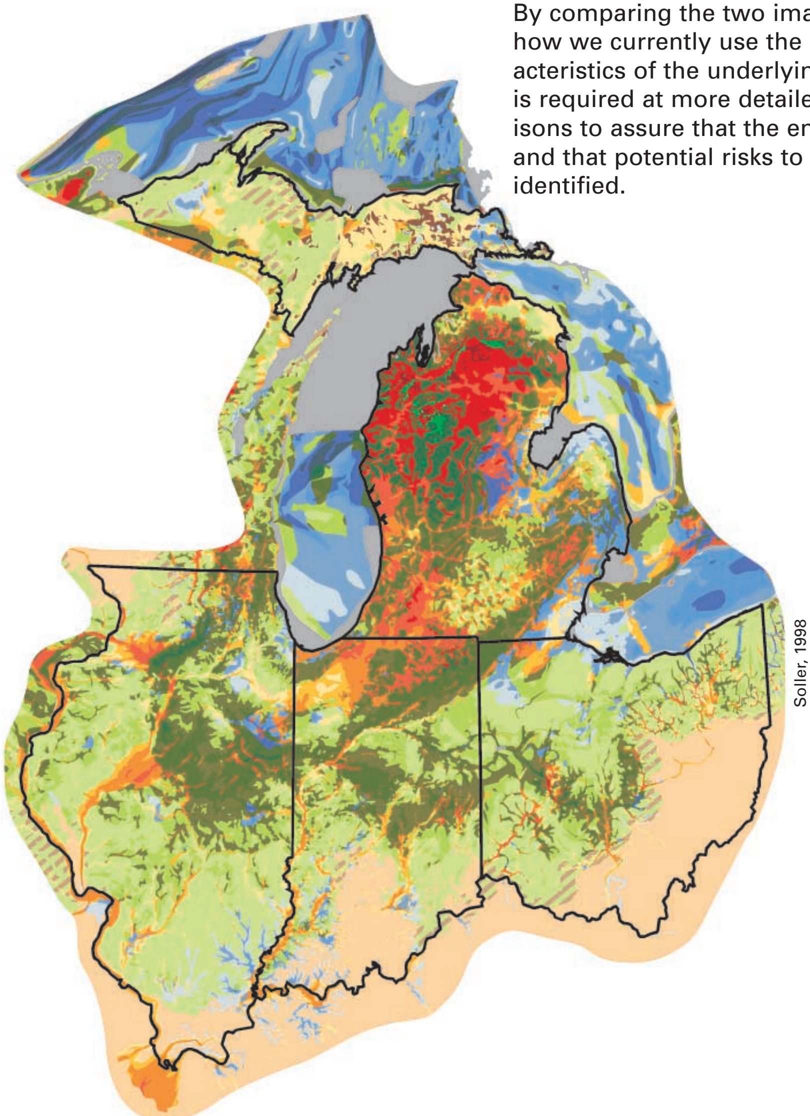
Illinois State Geological Survey

Layered and sorted sand and gravel deposited by glacial meltwater.

U.S. Geological Survey

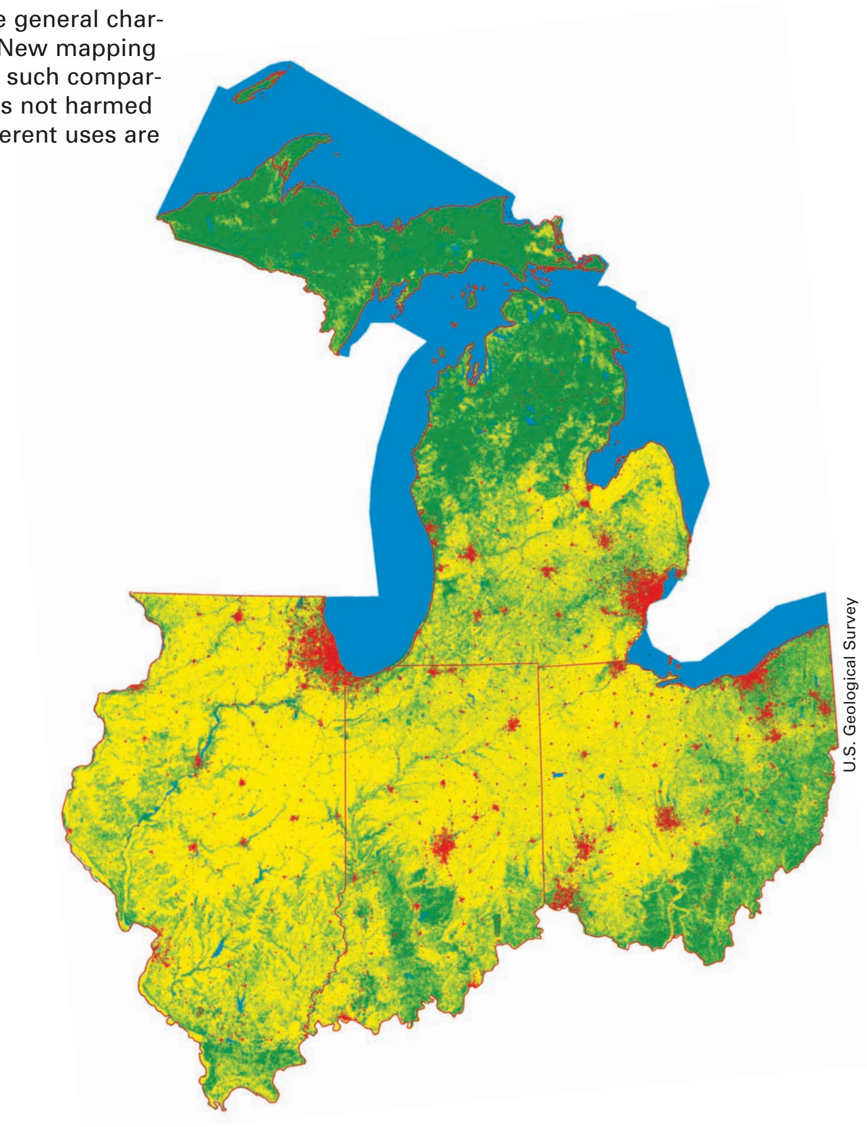
Glacial grooves carved by ice or by water beneath the glacier.

By comparing the two images below, one can see how we currently use the land and the general characteristics of the underlying geology. New mapping is required at more detailed scales for such comparisons to assure that the environment is not harmed and that potential risks to land for different uses are identified.



Major Surficial Deposits—Thickness and Character
[Darker colors indicate thicker deposits]

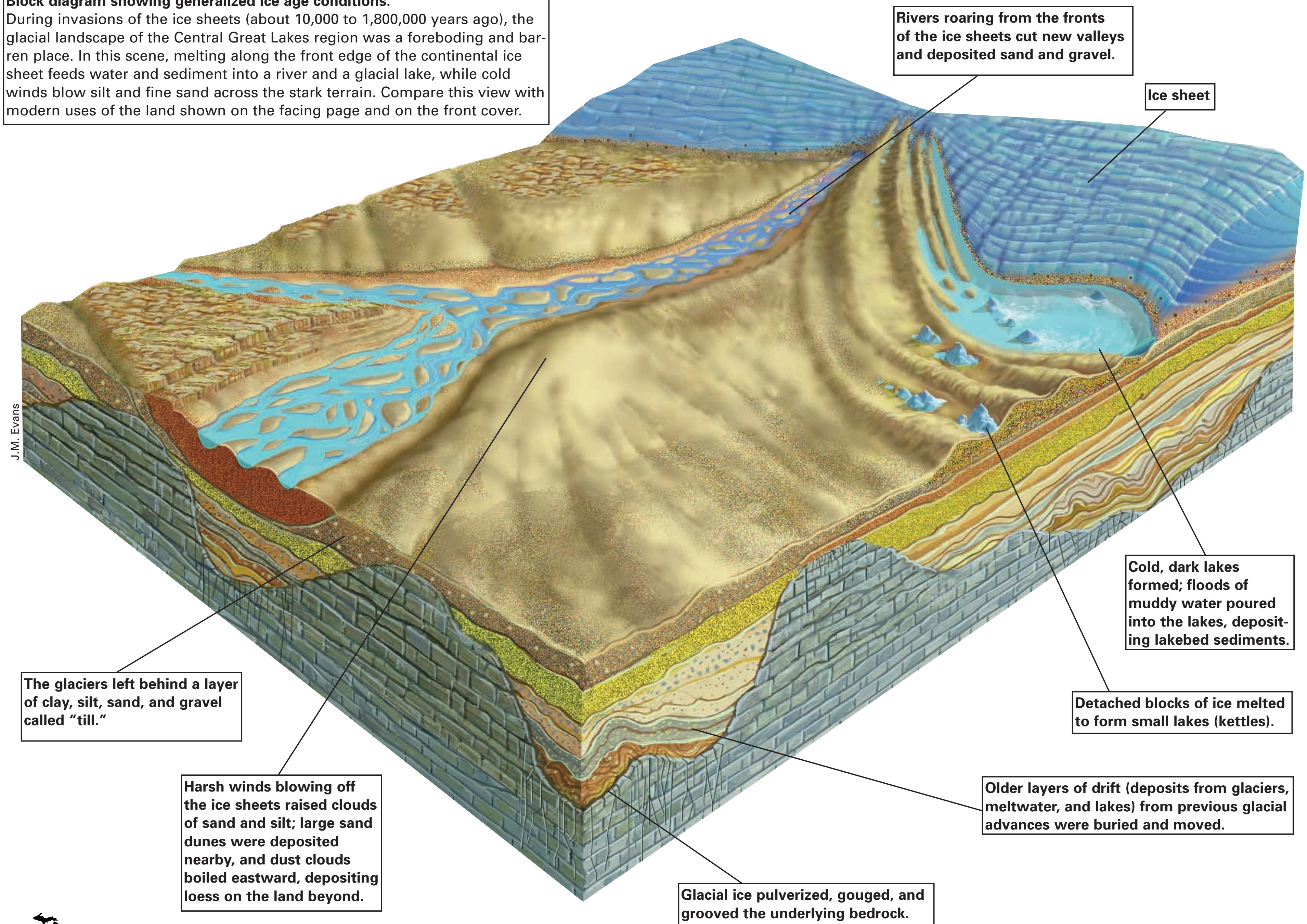
Sand and gravel | Silt and clay | Till | Unglaciated and periglacial areas | Loess | No data



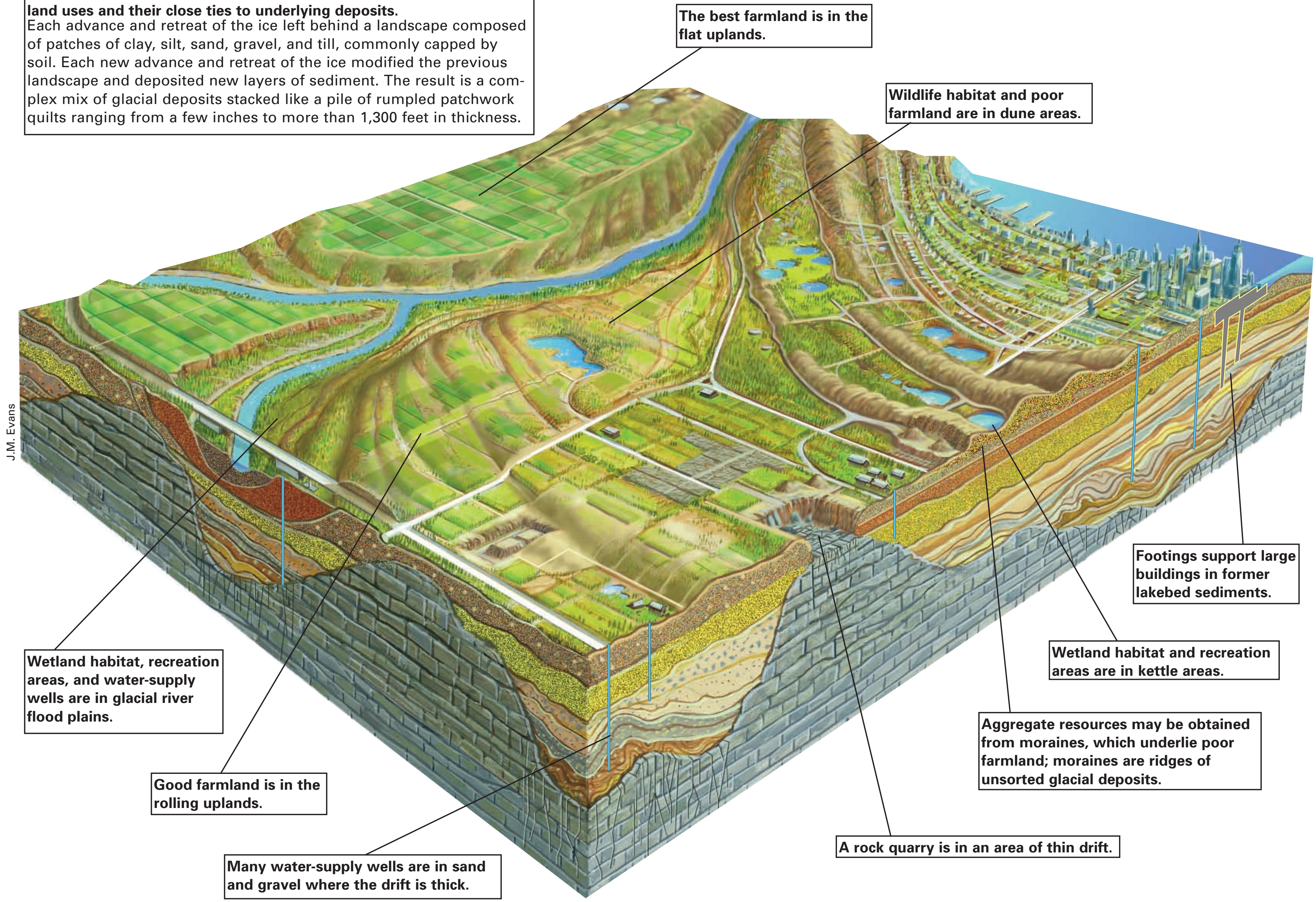
Land Use

Urban/suburban | Agriculture | Forest | Water

Block diagram showing generalized ice age conditions.
During invasions of the ice sheets (about 10,000 to 1,800,000 years ago), the glacial landscape of the Central Great Lakes region was a foreboding and barren place. In this scene, melting along the front edge of the continental ice sheet feeds water and sediment into a river and a glacial lake, while cold winds blow silt and fine sand across the stark terrain. Compare this view with modern uses of the land shown on the facing page and on the front cover.



Block diagram showing a generalized representation of modern surface land uses and their close ties to underlying deposits.
Each advance and retreat of the ice left behind a landscape composed of patches of clay, silt, sand, gravel, and till, commonly capped by soil. Each new advance and retreat of the ice modified the previous landscape and deposited new layers of sediment. The result is a complex mix of glacial deposits stacked like a pile of rumpled patchwork quilts ranging from a few inches to more than 1,300 feet in thickness.



NEW TOOLS TO COLLECT AND ANALYZE EARTH SCIENCE INFORMATION

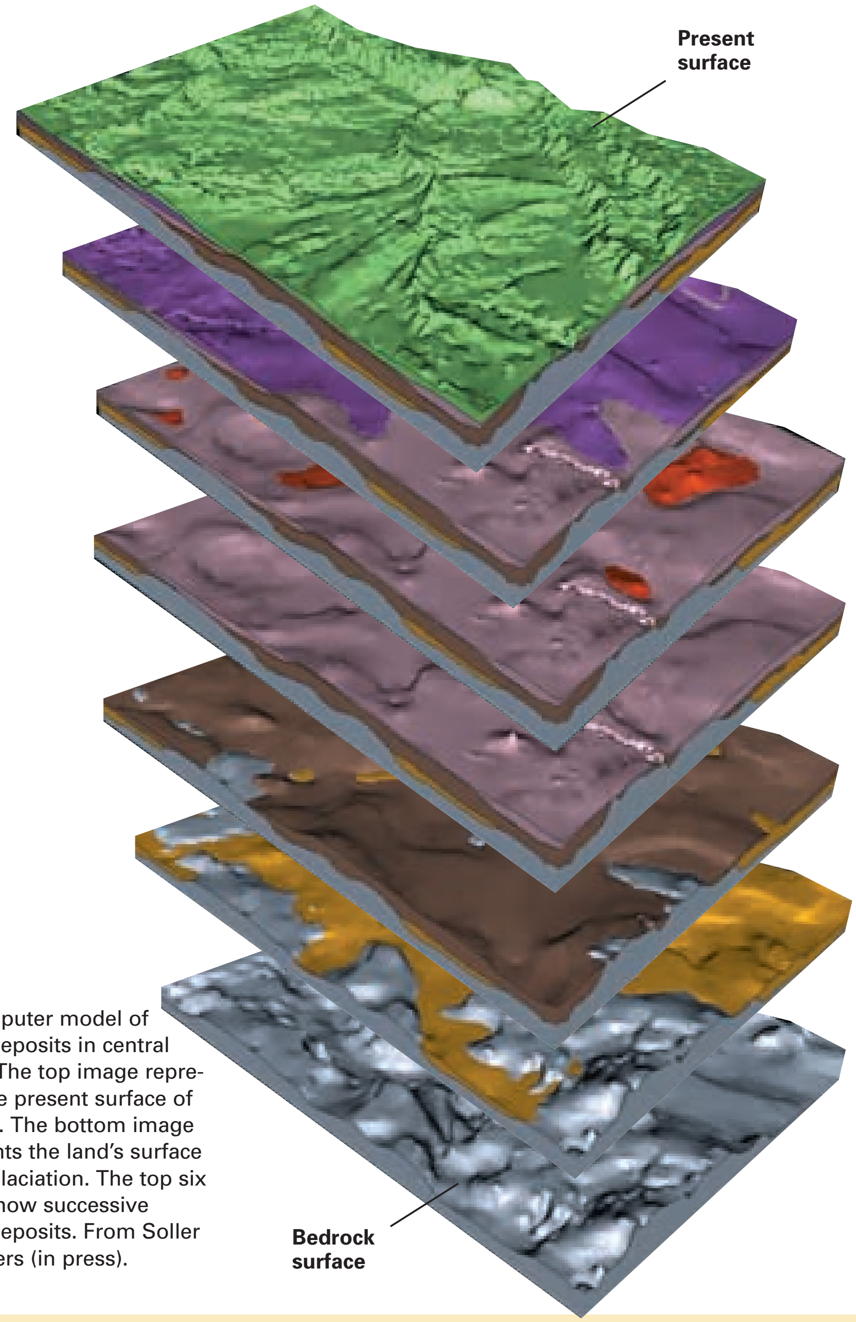
Advanced computer technology and new scientific capabilities are expanding our ability to see what lies beneath the surface of the land. These new tools provide geologists with new ways to characterize, organize, analyze, and display in three dimensions the complicated pattern of sediment layers that the glaciers left behind.

Geophysical tools to see layers beneath the land surface, developed in the petroleum and mineral exploration industries, increasingly are being modified for use in surficial geology, ground-water, and environmental studies. These technologies are being adapted to investigate the 3-D distributions of materials in glacial deposits.

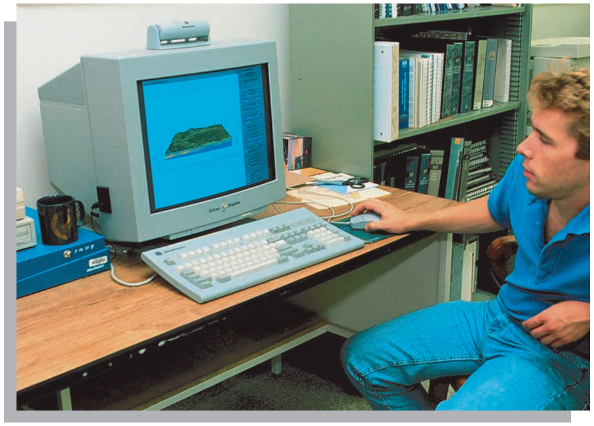
Core samples of subsurface deposits provide material for detailed geologic, geophysical, and geochemical studies. Techniques for obtaining undisturbed core samples of loose surficial materials have improved in the last decade. To deploy new types of coring devices in previously inaccessible areas, vehicles such as Hovercraft are being utilized.

With **advanced computers** and geographic information systems (GIS), today's geologist can move beyond the two-dimensional paper map of materials at the Earth's surface to produce elegant, three-dimensional pictures to portray precise physical and chemical analyses of surficial materials from the surface down to bedrock. These new capabilities are revolutionizing the way earth science information is gathered and used. For the first time, geology, hydrology, biology, and social science information can be integrated to show the human, ecosystem, and geologic histories of an area and to model and show the potential societal effects of proposed land-use management options.

Decision-support systems integrate all of this new information. They can be used by managers working with geologists to evaluate many scenarios and make the most reasonable decisions for land and resource use. These science-based systems are the ideal foundation for evaluating land-use planning options for sustainable and environmentally friendly development. The resulting models are easily managed and updated as new data become available or as new scientific insights require reinterpretation.



3-D computer model of glacial deposits in central Illinois. The top image represents the present surface of the land. The bottom image represents the land's surface before glaciation. The top six layers show successive glacial deposits. From Soller and others (in press).



Illinois State Geological Survey

Computer model of glacial material.

U.S. Geological Survey

Drilling equipment obtaining data for modeling the subsurface.

U.S. Geological Survey

Hoverprobe drilling in an area not accessible by boats or trucks.

Some new geophysical and sampling tools:

- Advanced computers and GIS technology allow the geologist to see and model surface and buried surficial materials.
- High-resolution sensors measure properties of surficial materials in wells.
- Cameras and sensors make images of drill-hole walls.
- Airborne surveys can map electromagnetic and magnetic properties and natural radiation of surficial materials in two dimensions and sometimes in three.
- Ground-penetrating radar and seismic methods show reflections of buried layers.
- Waterborne surveys can map sediment characteristics on the bottoms of lakes and streams.
- Drilling tools collect undisturbed core samples.
- Barges and Hovercraft support drilling in shallow water and sensitive environments.

U.S. Geological Survey

Geologists studying earthquake effects on and beneath a bridge.

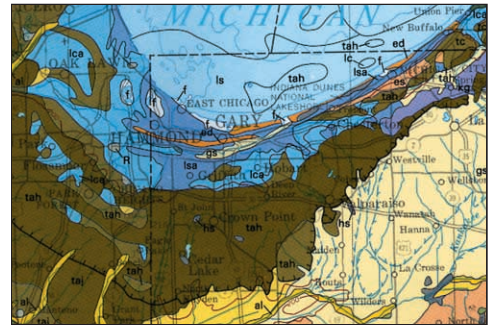
U.S. Geological Survey

Airborne equipment collecting geophysical data for modeling the subsurface.

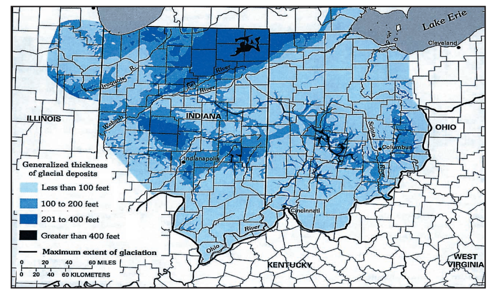
WHAT CAN BE DONE?—A COALITION TO ADDRESS THE ISSUES

Providing the sound earth science information necessary to help resolve major societal issues in the Central Great Lakes region is beyond the capability of any single earth science organization. Therefore, the State Geological Surveys of Illinois, Indiana, Michigan, and Ohio and the U.S. Geological Survey have formed the Central Great Lakes Geologic Mapping Coalition. Its mission is to produce detailed, 3-D surficial geologic maps, derivative map products, and digital data bases. These products will support various user communities in their decisionmaking processes. Through cooperative interactions and education of the broad user community, the Coalition seeks to make its information available and used as widely as possible.

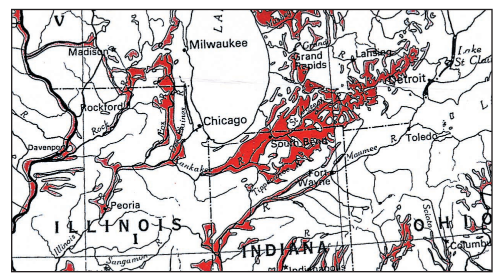
The Coalition proposes to conduct a cooperative surficial geologic mapping program that focuses on societal issues in high-priority areas across the region. The program emphasizes detailed geologic map products, at the quadrangle-map scale of 1:24,000 (1 inch on the map represents 2,000 feet on the ground), including new 3-D surficial geologic maps, as well as traditional surficial geologic maps. Geologic maps at this detailed scale are the optimum for addressing societal problems. Such maps depict sequences of surficial materials in adequate detail to be useful in identifying aquifers and sand and gravel resources. They can also be used to evaluate aquifer sensitivity to contamination. These maps identify geologic materials at construction- or environmental-site investigations. Regional surficial geologic map products at 1:100,000 scale will provide information for large areas where data are sparse, due to low population density, and where detailed mapping is unlikely to proceed in the immediate future. Regional surficial geologic maps also can be used to depict important bodies of surficial materials and trends that extend across county and State boundaries. Mapping at both scales provides a geologic context for resolving or evaluating regional societal or technical problems, as well as for interpreting the site-specific information generated by geologic consulting firms.



Competition for the land . . .
Define, map, and assess surficial materials, groundwater aquifers, sand and gravel, and ecosystem resources, their historical production and preemption, and their possible sustainable production.



Water resources . . .
Determine the distribution and hydrogeologic characteristics of glacial aquifer systems, their connection to bedrock aquifers and surface water bodies, trends in water use, and vulnerability to contamination.

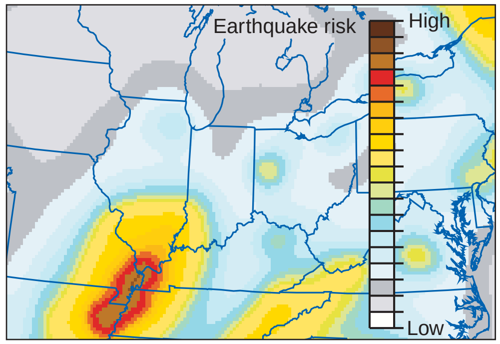


Construction materials . . .
Determine the surface and subsurface distribution, grain size, composition, and production trends of sand and gravel resources.

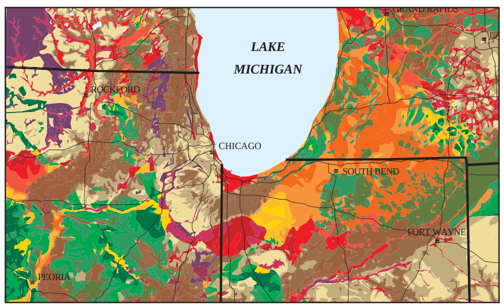
Coastal erosion . . .
Determine historical shoreline recession rates and erodibility of onshore and offshore materials; identify active Earth-surface processes. Help evaluate disastrous erosion events as part of emergency response teams.

Floods . . .
Delineate the active flood plain, calculate intervals of flood recurrence, and assess historical flood erosion and sedimentation. Help evaluate disastrous floods as part of emergency response teams.

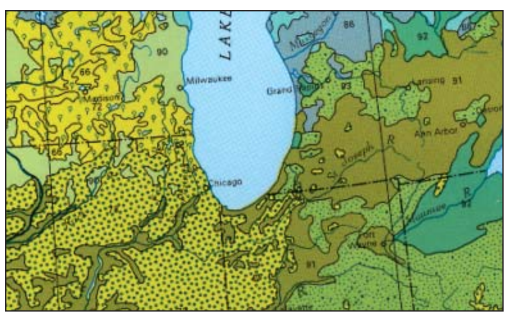
Earthquakes . . .
Determine distribution and geotechnical characteristics of surficial materials that are susceptible to seismic liquefaction or slope failure. Help evaluate disastrous earthquakes as part of emergency response teams.



Contamination of land and water . . .
Determine natural baseline geochemistry of surficial materials and identify processes and history of interaction with ground water and toxic substances.

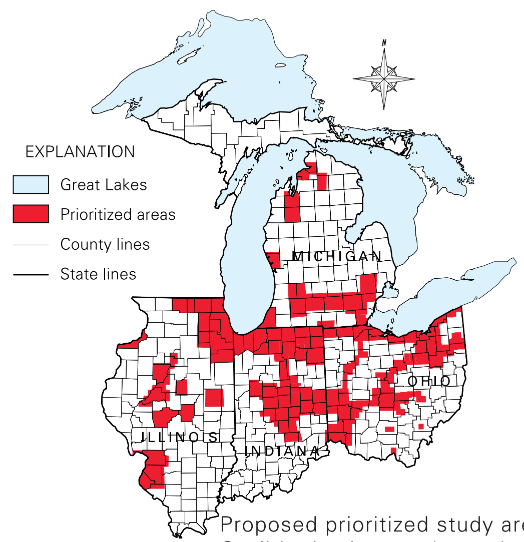


Ecosystem change . . .
Determine how Earth-surface processes and glacial landforms controlled presettlement ecosystems as a basis for managing, preserving, or restoring present ecosystems.



Areas for mapping will be prioritized (see map below) to serve the needs of customers and clients in both the private and public sectors. Work will be accomplished in partnership with other earth and natural science groups and agencies.

The Coalition's surficial geologic mapping program is a ground-breaking State-Federal collaborative effort that incorporates several important innovations. The five Geological Surveys will share scientific staffs and facilities to streamline mapping and subsurface investigations, develop integrated data bases, and use state-of-the-art computer models. The Surveys will identify local and regional societal issues with local stakeholders to focus mapping activities in high-priority areas. A regional geologic information delivery system will be established to announce and distribute digital maps and data bases to all stakeholders. In addition, a public outreach program will be implemented to educate stakeholders in the use of Coalition information. In this effort, decisionmakers will learn to use new mapping techniques in analyzing 3-D data. Finally, the program will enhance communication between scientists and public- and private-sector policymakers.



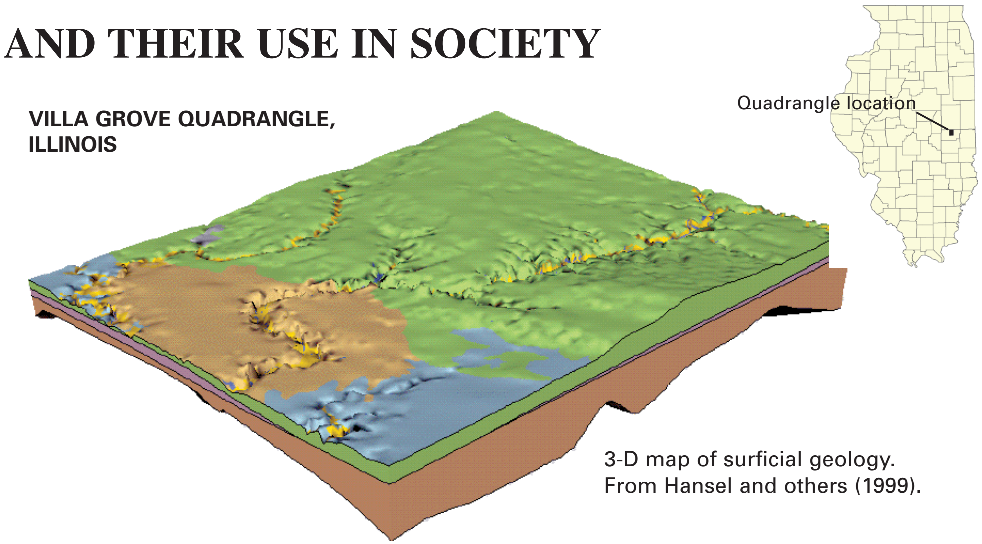
Proposed prioritized study areas from the Coalition's plan, as determined by customers.

COALITION PRODUCTS AND THEIR USE IN SOCIETY

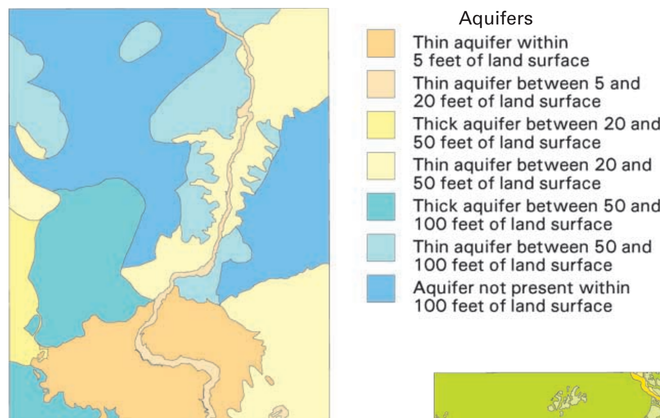
The Central Great Lakes Geologic Mapping Coalition will produce detailed, 3-D, computerized geologic maps of the surficial materials overlying bedrock in the glaciated regions of the four Central Great Lakes States. This primary data set includes the 3-D geology and characteristics of the various layers of surficial materials. Priority study areas will be targeted in cooperation with the user community to address resource and hazard issues in urban and suburban settings, transportation and industrial corridors, and environmentally sensitive zones.

New map products and 3-D models can be derived from the primary data set to help meet user needs on specific issues. These 3-D computer models can be rotated, sliced, and separated by the geologists and information users to visualize buried layers of surficial materials and aquifers in the subsurface. In addition, the primary and derived geologic products can be coupled with extensive hydrologic, biologic, geographic, socioeconomic, and other data bases to form the nucleus of a powerful information system. This system will provide a comprehensive decision-support tool for resolving complex and difficult societal land-use issues for landowners and decisionmakers in governmental, educational, industrial, and environmental organizations.

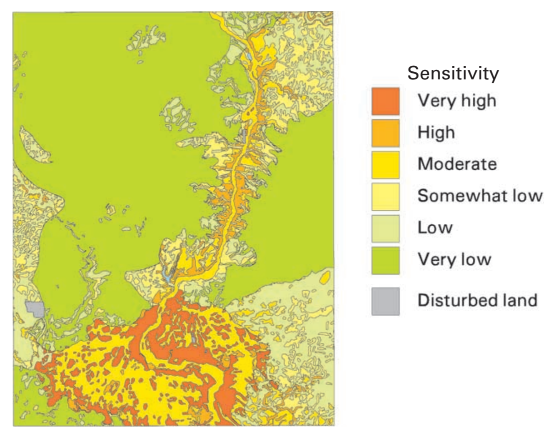
As part of the Coalition's outreach program, Coalition scientists will provide map products in easy-to-understand formats that are tailored to resolve specific local resource or hazard issues. Where possible, decision-support systems will illustrate the probable outcomes of alternative courses of action. Coalition outreach personnel will help users develop skills in using the information system and will provide feedback to Coalition scientists to respond to user requests for modifications and extensions to the system.



3-D map of surficial geology. From Hansel and others (1999).



Map showing aquifers. From Berg and Abert (1999).



Map showing aquifer sensitivity to nitrate contamination. From Berg and Abert (1999).

Illinois State Geological Survey

An active geologic mapping program brings opportunities for student and community involvement.

U.S. Geological Survey

Geologist pointing out features of glacial material.

The objective of the Coalition is to provide earth science information that can support sound, unbiased, and cost-effective land-use decisions. Results of alternative plans to restore, preserve, or sequentially develop mineral, water, and environmental resources can be modeled, thus avoiding resource loss or overregulation. The Coalition will seek to increase communication among scientists and resource decisionmakers in public, private, educational, and environmental sectors.

Coalition scientists cannot do all of the proposed work alone. The scientific breadth and magnitude of the work require the cooperation and input of scientists from many other earth science disciplines and from academia, other State and Federal agencies, and the private sector. To meet the increased need for surficial geologic mappers, additional students must be trained. The Coalition scientists and cooperators will develop 3-D descriptions of the subsurface geology that are consistent throughout the central Great Lakes States and can be broadly extended to other regions of the Nation.

Increased communication between these scientists and the user community will help assure that the information is understood and appropriately used. Scientists will be trained to help improve intergovernmental cooperation and communication. Decision-support systems developed within this program will serve as a model for other earth science activities across the Nation.

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CAPTIONS FOR FIGURES ON PAGES 10 AND 11

Page 10 (figures from top to bottom)

Surficial geologic map of the Chicago, Illinois, and Gary, Indiana, area. From Lineback and others (1983).

Map showing glacial aquifer location. From Casey (1996).

Map showing areas with potential aggregate resources. From Langer (1988).

Photograph showing the former location of streets and homes lost by the erosion of the Lake Erie shoreline. From U.S. Geological Survey (unpub. data).

Page 11 (figures from top to bottom)

Composite satellite image of the Missouri River flood plain after the record flood of 1993. From Scientific Assessment and Strategy Team (1994, p. 107).

Map showing the potential for earthquake hazards in the Central Great Lakes States. From U.S. Geological Survey (available on the World Wide Web at http://geohazards.cr.usgs.gov/eq/hazmaps/250pga.pdf).

Map of the southern Lake Michigan area showing the potential vulnerability of ground water to contamination. Red areas have the greatest risk, green areas have the least risk. From Soller and Berg (1992).

Potential natural vegetation map of the southern Lake Michigan area. The map shows the vegetation communities that would naturally occur if there were no human disturbance in the area. From U.S. Geological Survey (available on the World Wide Web at http://www.nationalatlas.gov/atlasmap.html).

What information is needed by managers and decisionmakers in the region?

E.J. Fellows, U.S. Environmental Protection Agency

"For the National Watershed Assessment Project, geology is the major missing data layer."

T.H. Tear, Director of Conservation Science, The Nature Conservancy of Illinois

"There has been a high rate of failure of restoring wetlands because sites have been selected that do not properly link the site hydrology to its geologic setting. In response to this, the Illinois Nature Conservancy has identified several areas that would be ideal to accomplish their restoration goals and insists that sites be in geologically appropriate areas. Working with the Geological Survey in the early stages is important, and should be seen as an essential and primary step in developing successful restoration projects."

R. Duncan, Indiana Department of Environmental Management

"Delineation of 5-year travel time [of ground water] requires the use of geology to see where the regulations need to be applied."

S. Esling, Associate Professor of Geology, Southern Illinois University

"The original attempt at siting a low-level nuclear waste repository failed because geology did not play a big enough role in the process."

B. Grant, Toxicologist, LaGrange County Health Department, Indiana

"We run centuries old disposal methods of septic systems and manure spreading on much higher densities than ever intended."

T. Bruns, Director of Development Services, Indianapolis Water Company, Indiana

"You need to define geology and make it available in digital databases to serve customers."

M. Johnson, Vice President, Northern Illinois Water Corporation

"Regional geologic mapping is critical to integrated management of aquifers."

Central Great Lakes Geologic Mapping Coalition—
A State-Federal Partnership to Address Vital Societal Issues

The Illinois State Geological Survey (of the Illinois Department of Natural Resources), created in its modern form by legislative mandate in 1905, provides objective scientific information to government, business, and the public. The work is guided by two major objectives—

- To improve the quality of life for Illinois citizens by providing the scientific information and interpretations needed for developing sound environmental policies and practices.
- To strengthen the Illinois economy by promoting wise development of the State's abundant mineral resources.

The Indiana Geological Survey, which is an institute of Indiana University, was established in 1837; it has a statutory mission—

- To provide geologic information and counsel that contribute to the wise stewardship and economic development of the energy, mineral, and ground-water resources of Indiana.

The Indiana Geological Survey works to discover and promote the development and conservation of these resources; maintains geologic data bases and sample libraries; investigates geologic hazards and environmental issues; and disseminates information through public education, maps and reports, and consultation with the public.

The Michigan Geological Survey Division (of the Michigan Department of Environmental Quality) is the oldest Michigan State agency; it was established in 1837, the same year that Michigan was admitted to the Union. The mission of the Michigan Geological Survey Division is—

- To encourage conservation and protect natural resource values in developing the geological resources of the State, including fossil fuels, minerals, and ground water.
- To identify, develop, and disseminate geological information for the benefit of Michigan citizens.

The Ohio Division of Geological Survey (of the Ohio Department of Natural Resources) is Ohio's oldest natural resources agency; it was established in 1837 to investigate the geology and mineral resources of the State of Ohio. The mission of the Ohio Division of Geological Survey is—

- To provide geologic information and services needed for responsible management of Ohio's natural resources.

The U.S. Geological Survey, established in 1879, is an earth science organization within the U.S. Department of the Interior; the USGS is recognized worldwide as scientifically credible, objective, and demonstrably relevant to society's needs. The mission of the USGS is—

- To provide the Nation with reliable, impartial information to describe and understand the Earth.

This information is used to minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; enhance and protect the quality of life; and contribute to wise economic and physical development.

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