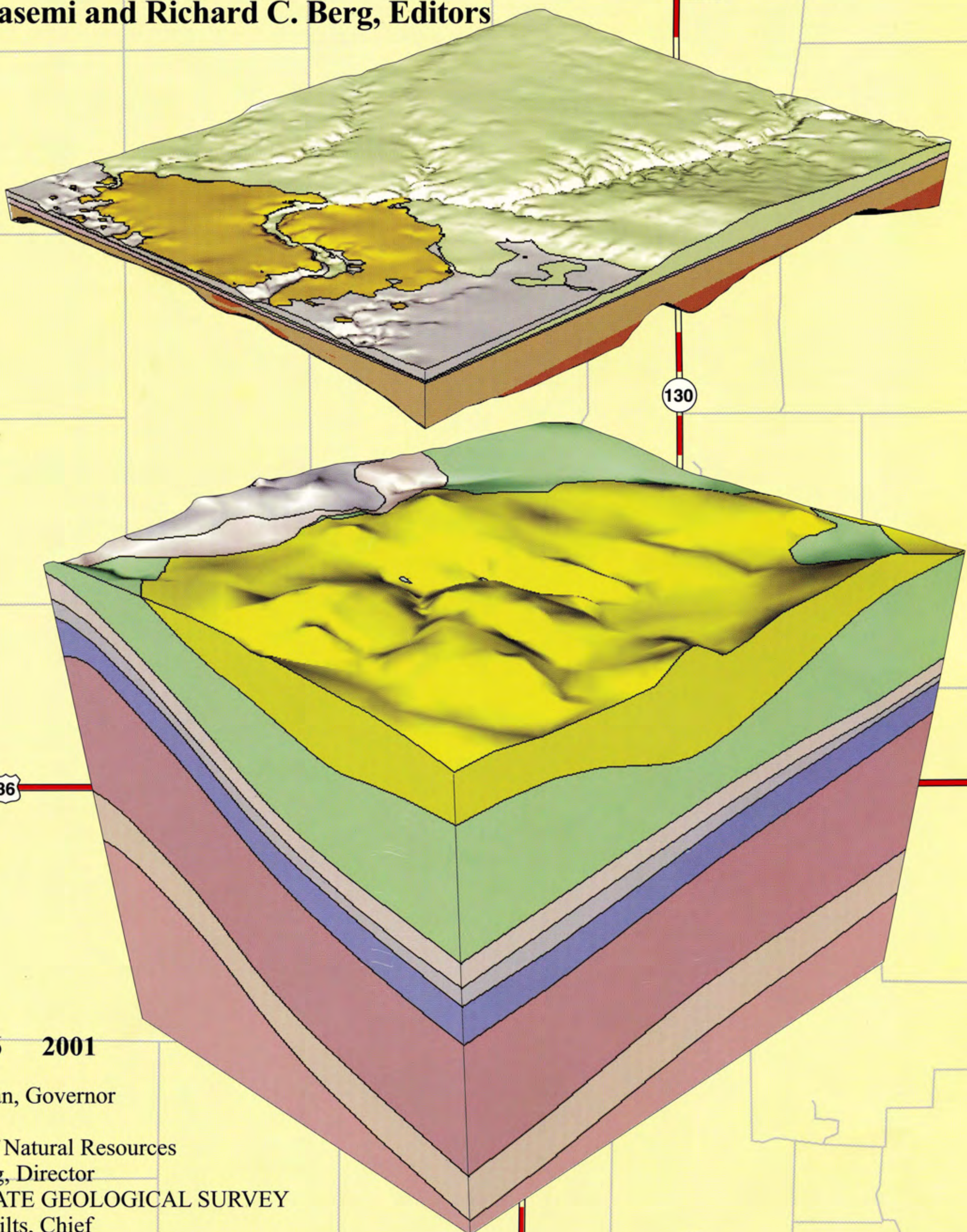
Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois

Zakaria Lasemi and Richard C. Berg, Editors



Bulletin 106 2001

George H. Ryan, Governor

Department of Natural Resources
Brent Manning, Director
ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief

Abbreviations

2-D, two-dimensional
3-D, three-dimensional
B&W, black and white
CIR, color infrared
DLG, digital line graph
dpi, dots per inch
DRG, digital raster graphics
EV, EarthVision
GIS, geographic information system
gpd, gallons per day
gpm, gallons per minute
IEPA-PWS, Illinois Environmental Protection Agency, Public Water Section
IGMaP, Illinois Geologic Mapping Advisory Committee
ISGS, Illinois State Geological Survey
NAPP, National Aerial Photography Program
NCGMP, National Cooperative Geological Mapping Program
TDS, total dissolved solids
TRU, transgressive-regressive unit
USGS, United States Geological Survey

Front Cover: Three-dimensional stratigraphic models of the Villa Grove Quadrangle. See Chapter 3 for details.

Inside Back Cover: Topographic map of the Villa Grove Quadrangle.

Back Cover: Color infrared satellite view of east-central Illinois. See Chapter 4 for details.

Printed by the authority of the State of Illinois *PRT3240931 - .8M - 12/01*
printed using soybean ink on recycled paper

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois

Zakaria Lasemi and Richard C. Berg, Editors

Bulletin 106 2001

George H. Ryan, Governor

Department of Natural Resources
Brent Manning, Director
ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief
Natural Resources Building
615 East Peabody Drive
Champaign, IL 61820-6964
Home page: http://www.isgs.uiuc.edu/

Acknowledgments

The Villa Grove mapping project, culminating in this bulletin, would not have happened without the inspiration and encouragement provided by Chief William W. Shilts. Numerous other people within the ISGS provided valuable assistance; these include Ellen M. Wolf, who provided much assistance in the initial stages, Cheryl K. Nimz, Thomas N. McGeary, Jacquelyn L. Hannah, Joel M. Dexter, Pamella K. Carrillo, Michael W. Knapp, and Cynthia A. Briedis, all from the Publishing, Design, and Photography Section of the ISGS. Lisa R. Smith worked on assembling and verifying the well and boring database, assembling the soils data, and assembling ancillary geospatial data during the early stage of the project. The Geological Records Unit and the Geologic Samples Library assisted in obtaining information on drilled wells and cores in the area. H.D. Glass ran x-ray analyses of clay minerals to assist in deciphering Quaternary stratigraphy. Geophysical logging by Timothy C. Young on a number of core holes provided valuable information on bedrock and Quaternary stratigraphy and groundwater resources. We thank Brian Arneson, Richard A. Cahill, Ray L. Henderson, John D. Steele, and Yanhong Zhang for geochemical analyses. We also appreciate the efforts of our reviewers who not only provided timely reviews of various chapters but also assisted the authors in various ways. These include, along with most of the authors, Jonathan H. Goodwin, Robert A. Bauer, Michael L. Barnhardt, Heinz H. Damberger, Joseph A. Devera, Beverly L. Herzog, Randall E. Hughes, Dennis R. Kolata, Robert J. Krumm, David R. Larson, John M. Masters, Edward Mehnert, David G. Morse, W. John Nelson, and Wen-June Su. We thank numerous individuals on the administrative staff for word processing, logistical, and financial assistance.

We also thank Randy Reed, the superintendent of Tuscola Quarry Company, who graciously allowed numerous visits to the quarry to collect data and examine cores in their possession. A.E. Kleiss and J. Prosser and family kindly permitted the drilling of the two scientific wells on their properties. Geotechnical data were provided by Walter Hanson, Donald Oglesby, and Daniel Kerns (Hanson and Associates, Inc.); Douglas Hambley and James Nelson (Graef, Anhalt, Schloemer & Associates, Inc.); and Riyad Wahab, Alan Goodfield, and Steve Robinson (Illinois Department of Transportation).

Foreword

Foreword

This bulletin documents three years of geologic investigations in the Villa Grove Quadrangle. The report provides a detailed example of modern mapping technologies, interdisciplinary teamwork, and service to the people of Illinois.

This quadrangle is the first to be completely mapped in three dimensions as part of the Illinois State Geological Survey's ambitious program to map the geology of Illinois at the detailed scale of 1:24,000 (1 inch = 2,000 feet). The program's goal is to map each of the state's 1,071 7.5-minute quadrangles in three dimensions from land surface, through the glacial materials, and into the bedrock.

Geologic maps at the 1:24,000 scale are the current national standard for mapping applications, especially base maps, geographic information systems, and digital applications. This level of detail is especially useful in providing regional information about geology to planners making decisions regarding water and mineral resources, regional growth strategies, environmental protection, sustainable development, waste facility siting, and reduction of geologic hazards.

The Villa Grove Quadrangle was chosen as the site of the pilot project for the ISGS's 1:24,000-scale, three-dimensional geologic mapping program. The pilot mapping effort was used to establish procedures and standards for field data collection, laboratory analyses, database development, map layout and design, map production, and outreach activities that will evolve as the mapping effort continues throughout the state. New technologies and computer software were combined with standard techniques to provide as much information about the quadrangle as possible.

During the project, a dedicated team of scientists from various subdisciplines of geology worked together and with GIS and graphics specialists to compile geologic databases and map products that can be updated easily, interpreted for various uses, and understood by the general public.

This bulletin contains valuable information about the methodology used, basic data obtained, derivative map products created, and the best ways to represent the geology for end users. The eighteen chapters written by ISGS scientists discuss the geology of the Villa Grove Quadrangle and the economic and environmental interpretations derived from the study. Particularly important are discussions of the types of data required to conduct a three-dimensional (3-D) mapping program, the significance to society of basic geologic information, and the practical applications of those data.

The geologic information provided in this report, complete with detailed maps, cross sections, 3-D models, and interpretations of the geology, provides assistance to those who ultimately must make decisions that balance land use with economic development and environmental protection. Coupled with the many maps that have already been published for the Villa Grove project, this bulletin documents the directions that the ISGS plans to take its 3-D geologic mapping program. As the Illinois mapping continues, additional innovations and refinements are sure to follow. We believe that the teamwork, sound scientific methods, and technological improvements used in this project will form the basis of a successful and ongoing 3-D geologic mapping program throughout the state and the central Great Lakes region.

William W. Shilts, Chief
Illinois State Geological Survey

Contents

Figures

Tables

Introduction

Chapter 1

The Villa Grove Quadrangle Mapping Project

Richard C. Berg

STATUS OF GEOLOGIC MAPPING IN ILLINOIS

If the economy of Illinois were compared with those of the top countries in the world, the Illinois economy would rank about thirteenth, just above Australia and the Netherlands. The industries driving the Illinois economy, and the citizens benefiting from those industries, also use great amounts of water, mineral resources, and gas and oil; they generate waste; and they require a vast infrastructure to meet the needs and demands of expansion. Not surprisingly, Illinois has environmental and earth-resource problems of a scale similar to its economy.

As Illinois' population and economy have grown, state, county, and municipal (local) government officials are increasingly forced to make decisions that require detailed geologic information. Such information helps local officials assess groundwater and mineral resources to meet infrastructure and energy needs, identify suitable land areas for industrial growth and waste disposal, and maintain a high degree of environmental protection. The needed information is seldom available or easily obtained.

For example, Illinois ranks 49th among states in the amount of land remaining in its natural condition. Cultivated land dominates more than three-fourths of the surface area of the state. In addition, many geologic features have been obscured by 175 years of settlement. Currently, less than 5% of Illinois has been mapped geologically at the scale needed by decision makers and land use or environmental planners to optimize environmental protection and sensible resource extraction while minimizing environmental degradation.

Large-scale soil maps are available for each county in Illinois as a result of a decades-long collaboration among county, state, and federal agencies. County soil maps, many at a scale of 1:15,840 (1 inch on the map = 1,320 feet on the ground), are immensely valuable to the agricultural community and many other users. The soil maps have a single major shortcoming: they do not reveal the nature of materials below a depth of about 5 feet. Even though geologists at the Illinois State Geological Survey (ISGS) have been mapping both bedrock and glacial deposits since the early 1900s, most of the mapping to date has been at regional scales (1:250,000 to 1:1,000,000 scale). Only rarely has detailed subsurface information been represented on the maps. Although all parts of the state are covered by these regional geologic maps, the map information is highly variable in quality (Soller 1992), based in part on old surveys; in some areas, observations and geologic concepts are more than a century old. Traditional, more detailed geologic maps (1:24,000 to 1:125,000) cover only a small percentage of the state (fig. 1-1). Many of these maps, too, are based on older concepts and methods.

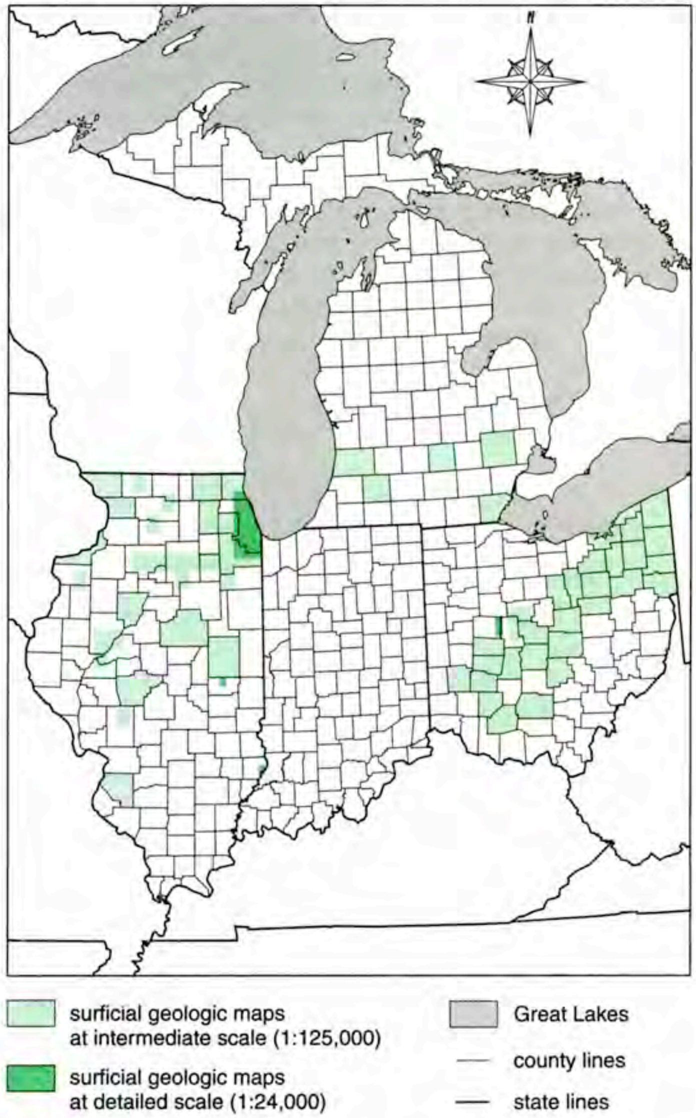


Figure 1-1 Areas in the central Great Lakes states represented on surficial geologic maps at scales of 1:24,000 to 1:125,000. Source: U.S. Geological Survey, Open File Report 99-349 (Berg et al. 1999).

ASSESSMENT OF MAPPING NEEDS

A considerable amount of advance planning has already been done in Illinois to prioritize each of the state's quadrangles for detailed geologic mapping. Early on, the ISGS sought the advice of the Illinois Geologic Mapping Advisory Committee

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

(IGMAC). Formed in 1989 as a formal geologic mapping review committee and composed of Illinois citizens, the IGMAC includes members from state agencies, non-governmental organizations, private industry, professional associations, and academic institutions, all with geologic mapping interests in Illinois. The committee's primary purpose is to advise the ISGS in setting priorities for geologic mapping done by the ISGS through federal funding from the National Cooperative Geologic Mapping Program (NCGMP). IGMAC annually reviews the progress of geologic mapping and reassesses priorities for mapping various regions.

In 1991, at the direction of the Illinois Senate, the ISGS conducted a statewide assessment of the need for geologic mapping for each quadrangle in the state based on 23 criteria, such as the presence of earth hazards, groundwater, and mineral resources (ISGS 1992). The highest priority areas generally were those undergoing rapid urbanization. Such areas urgently need detailed (1:24,000 scale) geologic maps to help anticipate and solve problems arising from the environmental consequences and resource demands of growth.

PILOT PROGRAM FOR THREE-DIMENSIONAL GEOLOGIC MAPPING: THE VILLA GROVE QUADRANGLE

In 1996, to further comply with recommendations from IGMAC and to better address the environmental and economic challenges faced by Illinois (ISGS 1996), the ISGS adopted an ambitious strategy to produce detailed geologic maps. The ISGS recognized that maps at a scale of 1:24,000 (1 inch = 2,000 feet) were needed to clearly show the complexity and variety of subsurface geologic materials so that local government officials and citizens could make meaningful and well-informed decisions concerning land use and environmental protection.

The ISGS proposed to map the geology and develop databases for all 1,071 of the 7.5-minute quadrangles in Illinois. The new three-dimensional (3-D) mapping program would map geologic deposits at the land surface as well as the geometry of geologic deposits at depth. The proposed mapping strategy was based on the use of multi-agency support to integrate expertise and information from all scientific disciplines at the ISGS and cooperating institutions.

A mapping venture of this magnitude had not been attempted before in Illinois. Therefore, in early 1996, pilot mapping areas were selected to determine the best approaches to this 3-D geologic mapping program. Two quadrangles were selected for pilot investigations: the Villa Grove Quadrangle in Douglas County, Illinois, and the Vincennes Quadrangle in Lawrence County, Illinois, and Knox County, Indiana.

This report presents the results of the ISGS pilot program for 3-D mapping of the Villa Grove Quadrangle at a scale of 1:24,000 (fig. 1-2; see also, topographic map, back cover). The first section of the report, *Methodology*, describes database development, computer modeling support, and remote sensing inputs to geologic mapping. The next section, *Basic Mapping*, discusses the basic geologic maps that were created for the

Figure 1-2 Location map of the Villa Grove Quadrangle.

mapping program, beginning with maps of the bedrock deposits (Silurian, Devonian, Mississippian, and Pennsylvanian) and concluding with maps of bedrock topography, Quaternary geology, and drift thickness. The final section, *Derivative Mapping*, discusses maps that are produced from the basic geologic maps. These derivative maps include maps of groundwater resources; aquifer sensitivity; engineering geology, natural hazards, and construction materials; mineral resources (aggregate); and coal resources.

The Villa Grove Quadrangle was selected primarily because (1) economically important aggregate resources are located in the quadrangle, (2) there are a variety of geologic features (both in the bedrock and glacial deposits) of interest to researchers at the ISGS, (3) the quadrangle is adjacent to an expanding small urban area (Tuscola), and (4) the proximity of the quadrangle to the ISGS in Champaign-Urbana reduced travel costs.

Also important in selecting the Villa Grove Quadrangle was the large number of projects by ISGS staff already underway in this quadrangle. The projects provided a foundation for a mapping project covering a broad range of scientific and economic interests. In particular, the ISGS had been engaged in a detailed study of Devonian and Silurian age rocks, which are exposed at the Tuscola Stone Company quarry and mined for construction aggregate. Quarry exposures, supplemented by about 1,500 feet of core, represented the best available data on the Silurian and Devonian for most of the Illinois Basin. The location of this quadrangle at the south end of the Tuscola Anticline (an upward-bending flexure in the Earth's crust), in combination with available subsurface data, also provided an excellent opportunity to examine the geology of this structural feature and to investigate potential oil, gas, and coal resources.

This project provided the chance to investigate the area's 3-D glacial geology, which for the most part is not well known in this area of Illinois. The Tuscola quarry has an extensive 35-foot-thick exposure that affords a rare view of deposits from three glacial episodes, separated by geosols, which could serve as a type section for deposits in this part of the state.

To conduct the geologic mapping project for the Villa Grove Quadrangle, a collegial team of geologists mapped the bedrock and glacial deposits of the quadrangle while geographic information system (GIS) specialists, database specialists, and graphic artists developed the final map and database products. The multi-disciplinary nature of the team was determined by the geological peculiarities of the quadrangle being mapped. It was important that the project staff have the expertise needed to (1) map both glacial deposits and bedrock of various ages, (2) evaluate the potential for coal and aggregate resources, (3) assess the potential for groundwater resources and evaluate the potential for groundwater to become contaminated, (4) evaluate construction conditions and earth hazards, and (5) compile project databases and produce computer-generated maps.

Each team member completed a specific assignment that complemented, but did not overlap, those of other team members. For example, new drilling was coordinated so that each borehole location satisfied the needs of both bedrock and glacial geologists. Single test holes were used to collect glacial and bedrock samples and to conduct downhole geophysical logging and testing.

LAND USE ISSUES IN THE VILLA GROVE QUADRANGLE

During the course of the mapping, team members conducted a needs assessment to focus their efforts and resources on the specific needs of the residents of the Villa Grove Quadrangle. The team contacted businesses and county agencies to learn what problems needed special attention. In addition, a field trip was held in July 1997 to give local residents the opportunity to discuss their most critical land use issues (ISGS 1997). On the basis of these assessments, the team identified the five most pressing needs.

1. ***Groundwater*** Residents stated that groundwater was mostly in short supply and that, in some areas, it also had a bad smell and taste. Finding an additional groundwater source for the Village of Villa Grove was important. Residents also wanted to know where and how deep they should drill for adequate water resources and whether the aquifers were vulnerable to contamination.
2. ***Flooding*** Flooding is a major issue along the Embarras River at Villa Grove. Residents asked why flooding happens and whether restoration of wetlands could ease the flooding. Unfortunately, the flooding problem can only be addressed partly by geologic investigations. Engineering studies of the river course, stream bank, and watershed are required to fully understand the effects of mitigation measures.
3. ***Development*** Although not a rapid growth area of Illinois, the Villa Grove Quadrangle still has land use pressures from landfills, a large shopping mall, industrial parks, railroad tracks and highways, and new houses and subdivisions with private septic systems and water wells.
4. ***Coal, oil, and gas resources*** Residents inquired about the availability of coal, oil, and gas; they were concerned about potential leaks from oil pipelines that cross the area.
5. ***Crushed stone aggregate*** The Tuscola quarry, located in the southwestern part of the quadrangle, is important for the local economy. Its long-term prospects for supplying the local market were a concern.

ADVANCED TECHNOLOGICAL PROCEDURES

The need for geologic maps and their derivative products (such as maps of potential for groundwater contamination) is increasing, and quick production of these maps and models is critical for the transfer of information and technology to state and local agencies and to the public. The digital technology used for this pilot-study effort reduced the number of tedious manual tasks, provided the scientists with views of the data from several perspectives, and increased the accuracy of the products. The GIS, which was used to compile the maps and associated data in digital form, was also the vehicle for producing maps for publication. All of the geological data were plotted on base maps, and cross sections and block diagrams were constructed to represent the continuity, shape, and thickness of subsurface geologic units and their stratigraphic relationships.

The beginnings of a standardized approach to 3-D geologic mapping, combining proven field techniques with the latest technological tools (including digital GIS), were developed for the Villa Grove project. Typical field procedures were combined with digital information that included orthophotographs, elevation models, raster graphics files of the topographic map, files made by scanning historic aerial photography, and files of soil data supplied by the Natural Resources Conservation Service.

All of the maps were derived as views of the digital database to ensure ease of adding data and modifying or updating map products as new data were generated. A 3-D model for both the bedrock and glacial deposits was a key map product from which other maps were derived. For the Villa Grove Quadrangle, an atlas of maps has been produced, and all available information has been included in a database, on a map, or both.

MODEL FOR LARGER THREE-DIMENSIONAL MAPPING PROJECTS

The methods used for the 3-D geologic mapping of the Villa Grove Quadrangle can serve as a model for other 1:24,000-scale mapping being conducted in Illinois and throughout the nation. Three-dimensional mapping of the bedrock and glacial deposits has been extended into four regions of Illinois: (1) the St. Louis Metro East area of Madison, St. Clair, and Monroe Counties, (2) Lake and McHenry Counties, (3) Peoria County, and (4) extreme southern Illinois. The mapping methods are also a model being highlighted by the U.S. Geological Survey (USGS) to promote a coalition of the state geological surveys of Illinois, Indiana, Michigan, and Ohio and the USGS. This coalition, the Central Great Lakes Geologic Mapping Coalition, was formed to map high-priority areas in detail and in three dimensions in the four states over a 17-year period (Berg et al. 1999, USGS 1999). Expertise, equipment, and funds to accomplish this task will be shared by the five surveys.

Lessons learned from the Villa Grove Quadrangle 3-D mapping program have provided considerable insight for developing the larger four-state Coalition mapping program, including its team-oriented approach, field and laboratory procedures, concepts of database and GIS development, map layout and design, and publication options. Moreover, the Villa Grove program provides insight on the huge level of effort required to conduct such a program and the need for adequate funding to provide extensive subsurface exploration, computer hardware and software to manage large databases, and adequately trained field geologists, database and GIS specialists, laboratory and field support, and graphic artists to conduct the mapping program from inception of ideas to publication of results.

REFERENCES

Berg, R.C., N.K. Bleuer, B.E. Jones, K.A. Kincare, R.R. Pavey, and B.D. Stone, 1999, Mapping the glacial geology of the Central Great Lakes Region in three dimensions—A model for state-federal cooperation: Reston, Virginia, U.S. Geological Survey, Open File Report 99-349.

Illinois State Geological Survey, 1992, Geologic mapping for the future of Illinois: Illinois State Geological Survey, Special Report 1 (prepared in cooperation with the Senate Working Committee on Geologic Mapping, assisted by the Senate Geologic Map Task Force), 21 p.

Illinois State Geological Survey, 1996, Break from tradition: Illinois State Geological Survey, Annual Report, 26 p.

Illinois State Geological Survey, 1997, New directions: Illinois State Geological Survey, Annual Report 30 p.

Soller, D.R., 1992, Text and references to accompany “Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains”: Reston, Virginia, U.S. Geological Survey, Bulletin 1921, 54 p.

U.S. Geological Survey, 1999, Sustainable growth in America’s heartland; 3-D geologic maps as the foundation: Reston, Virginia, U.S. Geological Survey, Circular 1190, 15 p.

Methodology

Chapter 2

Geologic Database

Alison B. Lecouris

Since 1854, scientists of the Illinois State Geological Survey (ISGS) and its predecessors have been collecting data to support their studies of the geology and mineral resources of Illinois. The Geological Records Unit at the ISGS has the mandated responsibility to act as the state repository for drill hole data and to collect and organize these data for easy access by Survey staff and the general public.

In 1968, the ISGS began entering oil, gas, water, and other well information into a computer database. Initial databases were sequential files, and users were few. The predominant emphasis was on data entry. In 1988, the ISGS acquired PC Oracle, a relational database management software package, and began developing a system called CONQuEST. The ISGS database now contains data for over 421,000 locations; the data include well permit and completion information, stratigraphic data, electric log availability, sample sets and cores available at the ISGS, and highway and bridge boring logs and engineering data.

The CONQuEST system is built around a central Oracle relational database. CONQuEST applications, written in the "C" programming language, have been developed to enable authorized users to easily enter, correct, retrieve, and otherwise maintain data in this central database. Data on the location and the kind of information (known as "header" data) are related to other data through the unique site identifier, the API number, as indicated in the relational database diagram (see fig. 2-1). Many cross-reference tables exist to speed the data entry process, enable data verification as the data are being entered, and facilitate significant disk storage savings by not storing redundant data. The data are protected by Oracle security and backup features and maintained by a database administrator.

PROCEDURE

Compiling and processing the information for the Villa Grove Quadrangle involved several steps. Most of the data for the 708 well locations had already been entered into the database system from earlier projects in the area. Logs from highway and bridge borings, particle-size analyses, sample set descriptions, and verified well locations were added to the database for this mapping project. In addition to well locations and details of the well logs, the database includes information about the elevation of the well collar, well status (e.g., water, engineering test), well name, and a unique identification number. All of the information was reviewed and entered into the ISGS database. Long descriptions of lithologic units were abstracted for the database.

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

It was essential to create comprehensive documentation, or metadata, for all the new data sets and maps. The metadata included (1) the source, nature, assessed quality, processing history, precision, and accuracy of the data; (2) notes on standards, rules, and procedures used in data generation; and (3) the processes used in data validation and verification. As geologists completed aspects of the Villa Grove Quadrangle mapping projects, the data in their individual databases were transferred to a central database, thereby decreasing the risk of the data being lost or destroyed. In addition, the potential for using obsolete data for future mapping was minimized because the replacement of old data by new data was documented. The database manager was responsible for the central database.

The database manager established guidelines and requirements for database design to ensure data consistency and usability; the manager sought input from other project staff on ways to improve the system and make it more user accessible. The manager also established data security measures to avoid data corruption and ensure that data could not be accidentally deleted. These procedures allowed for the creation and management of separate project databases and allowed for the preservation and sharing of data without data loss.

WELL LOCATION AND DATA VERIFICATION

A vital component of database management that benefited all aspects of the Villa Grove Quadrangle mapping program was verification of the locations of wells and borings, including private water wells, oil and gas wells, test borings, coal and aggregate mineral test borings, environmental test borings, and ISGS test borings. Once the location of a well or boring was verified, its log was immediately entered into the database. This procedure ensured that this information would be available for subsequent users of the database and that unnecessary re-verification of locations would not occur.

In some instances, wells having logs with high-quality geologic information could not be precisely located (perhaps because the well had been abandoned), but the general location was known. Regardless of the well's precise location, the geologic information on the log was still used to help establish the regional geologic framework and to compare its geologic information against perhaps less detailed but more accurately located well logs. This condition was noted in the database.

It was essential that all of the well log information (i.e., material descriptions) associated with a boring or well be as accurate as possible. The accuracy of material descriptions in well logs was verified by comparing older logs with logs for newly drilled test borings. Stratigraphic control borings, engineering borings, and water wells with detailed descriptions of geologic

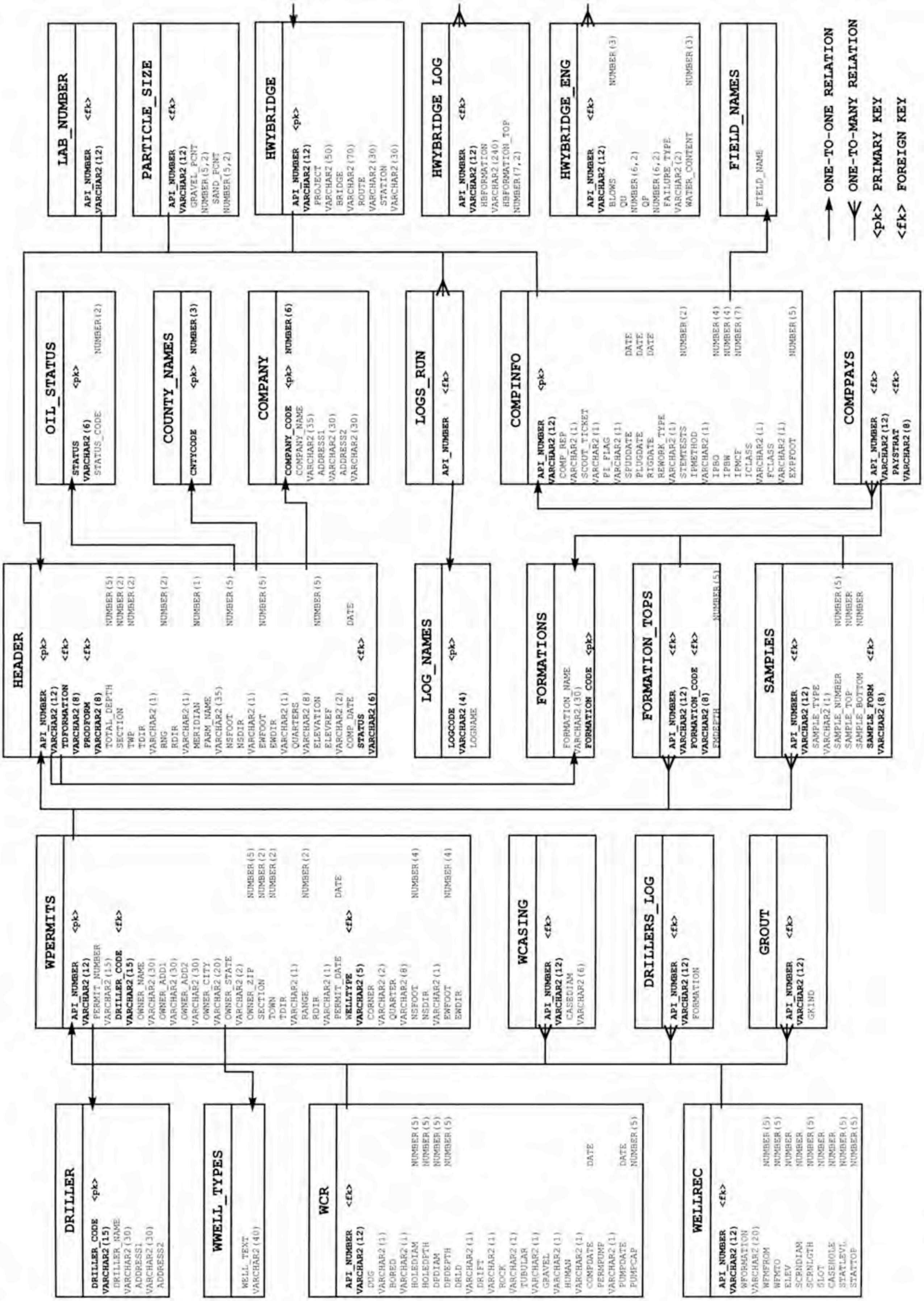


Figure 2-1 Relational database diagram.

materials were the highest-quality geologic data. Locations of these borings and their descriptions of materials were especially accurate because they were done by trained geologists or engineers. These borings were key stratigraphic control points, which were regarded as representative of the subsurface geology in a particular portion of the quadrangle. The deep drill holes bored specifically for this mapping project near Hugo (VGDH-1) and north of the Tuscola Stone Company quarry (VGDH-2) are examples of such key stratigraphic control points.

Locations for many water wells in the quadrangle were inaccurate and required verification by plat books or field checking. Furthermore, the descriptions of materials provided by some water-well drillers were overly simplistic for mapping purposes or were incomplete. Incompleteness was overcome to some degree by comparing the succession of geologic materials revealed in water-well logs against the succession revealed in a nearby key stratigraphic control point. If the two agreed fairly closely, then the water-well log had a higher probability of being accurate.

Quality assurance procedures were applied to review data and determine their quality. Quadrangle-wide screening of data for quality was accomplished initially by viewing computer-drawn maps and cross sections. In this procedure, individual well logs were viewed with respect to surrounding well logs, and well locations with anomalous data were identified and reviewed more carefully.

An essential component of the Villa Grove Quadrangle mapping program was the enhancement and management of the geologic database. If all available information could be collected, categorized, and easily retrievable as maps and/or data sets for each map sheet, then subsequent investigations could build on and add to the existing information. It was important that the database be easily accessible when mappers used it to enter and retrieve data and that these data could be easily transferred into various software packages to facilitate map production and geologic modeling and analysis using the most current information. The discussions in this volume by Abert (Chapter 3) on computer modeling, by Hansel et al. (Chapter 11) on the three-dimensional Quaternary geologic framework, and by Berg and Abert (Chapter 15) on aquifer sensitivity further explain how data were used to make various maps.

Chapter 3

Geographic Information System and Computer Modeling: Support, Methodology, and Applications to Geologic Mapping

Curtis C. Abert

The geographic information system (GIS) at the Illinois State Geological Survey (ISGS) has played a vital role in mapping the Villa Grove Quadrangle. A GIS is a collection of computer hardware, software, data, and personnel designed to capture, store, update, manipulate, analyze, and display geographic data (Environmental Systems Research Institute 1994). The primary GIS software used at the ISGS is Environmental Systems Research Institute's ARC/INFO software. The ISGS also uses EarthVision modeling software from Dynamic Graphics (1997) for two-dimensional (2-D) and three-dimensional (3-D) geologic modeling.

DATA ASSEMBLY

GIS was used to capture, organize, and analyze many varied data sets for the Villa Grove Quadrangle. Included were data from the ISGS well and boring database, the U.S. Geological Survey's digital raster graphics (DRG) file of the topographic map of the quadrangle, photographic images, previously published maps (at varied scales), and newly drafted maps and figures. The data initially had several projections, including Universal Transverse Mercator and Lambert Conformal Conic coordinate systems and datums. The Universal Transverse Mercator (zone 16, North American Datum of 1927) was chosen to be the standard projection and coordinate system for all the final data entering the quadrangle database because most existing data were in that projection.

Conversion of Land Surface Data

One of the basic data sets required in modern 3-D geologic mapping is a virtual 2-D representation of the land surface. Land surface elevation contours, found on every 7.5-minute quadrangle in Illinois, can be incorporated into a GIS in several ways, including hand-digitizing or scanning from published maps, purchasing digital files from the U.S. Geological Survey (USGS) or other data vendors, or converting them from the DRG file of the topographic map. For the Villa Grove mapping project, the contour lines were extracted from the DRG file.

The DRG is a georeferenced TIFF image that is produced by scanning a paper copy of the quadrangle map. The resulting image was resampled to a lower resolution of 150 dots per inch (dpi), georeferenced, and color-corrected. The colors stored in the image are limited to the thirteen standard colors found on 7.5-minute quadrangle maps. Surface elevation contours on the Villa Grove Quadrangle were brown (for index contours) or light brown (for intermediate contours). The TIFF image was converted to an ARC/INFO GRID geodataset, which stored values that relate to a corresponding table indicating which color is located at each sample point on the map. No information about actual surface elevation values, however, is stored in this particular GRID. From the original GRID, another GRID was created that contained only the two contour line colors. The two color values were simplified to a single value. ARC/INFO then converted the raster GRID geodata set to a vector coverage geodata set with the grid-to-line function. Because of the relatively low resolution of the original image (150 dpi), some blurring of the contour lines occurred. The blurred areas resulted in errors in the vector coverage, which were corrected as the vectors were manually attributed with corresponding surface elevation values. Although this vector coverage contained elevation data associated with topographic contour lines, a data set that contained a continuous surface of elevation data (including the areas between contour lines) was needed. ARC/INFO provides surface modeling tools, which were used to convert the vector contour line data set into yet another GRID that was a continuous representation of the land surface of the Villa Grove Quadrangle. The surface was prepared to USGS digital elevation model standards for 7.5-minute quadrangles and had a spacing of 30 meters between elevation points. This GRID was converted to an EarthVision format grid to provide the top surface of the 3-D geologic model.

Wells and Borings

Data from the ISGS well and boring database were retrieved and converted to an ARC/INFO point coverage. Included in the database were the x- and y-coordinates of each data point, as well as an elevation for some of the data points. However, much of the well data did not have an associated elevation. Using EarthVision, the well data points without elevations were projected onto the virtual land surface, and an elevation was interpolated for each well. The newly interpolated elevations were then brought back into the main GIS database of well data points, where elevations were calculated for the tops of subsurface geologic units described in the well logs and borings. Additional wells located near but outside boundaries of the Villa Grove Quadrangle were also obtained from the ISGS well and boring database. These additional wells were used in subsequent mapping and modeling to ensure that there were no "edge effects" at the borders of the quadrangle. Edge effects are caused by extrapolations of surfaces or units into areas where data are sparse or nonexistent. Elevations for these additional wells were obtained from the statewide digital elevation model, which has a spacing of 92 meters between elevation values. As a result, the elevations for these additional wells were not as accurate as those in the quadrangle.

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

EARTHVISION MODELING PROCEDURES

EarthVision uses 2-D and/or 3-D grids to model the thickness and areal extent of surficial and subsurface geologic units. A 2-D grid is a matrix or array of values, such as depth or elevation, which is used as a surface model in EarthVision (Dynamic Graphics 1997). EarthVision uses a global minimum tension gridding technique with several grid node assignment iterations to produce a surface representation from scattered data points. The minimum tension gridding algorithm results in a surface with the minimum amount of curvature (or tension). That is, the algorithm attempts to make a surface that does not sharply change the gradient between gently sloping and steeply sloping areas. One assumption made during the gridding process is that neither the highest nor lowest z value in the surface is found within the input data set, so extrapolation beyond the minimum and maximum values is allowed.

A 3-D grid is a matrix or array of values in x-y-z coordinate space that contains a property value at each coordinate (Dynamic Graphics 1997). EarthVision uses an extrapolation technique similar to the one used to produce 2-D grids. The gridding algorithm uses the following approach: for any given grid node, data points farther away have less importance than those nearer the grid node. In an initial evaluation, EarthVision considers the data surrounding each node and calculates (averages) a new value for that node. EarthVision then checks the newly assigned value of the grid node against the surrounding scattered input data values. As long as the difference between these values decreases, EarthVision accepts the new grid node value and continues with the averaging process. If the difference in values increases, EarthVision re-evaluates the grid node on the basis of the original scattered input data rather than on the surrounding grid nodes. The software initially creates a very coarse grid and repeats the averaging process until the final grid refinement (as specified by the user) is achieved. This iterative process has the effect of averaging all of the scattered data points. The averaging effect is most pronounced with input data that represent thin discontinuous units or lithologically variable units. This gridding algorithm is particularly useful for analyzing uncertain data, such as water-well logs, because the averaging tends to filter out routine reporting errors while preserving regional trends. The resulting model smoothly connects similarly coded (e.g., coarse- or fine-grained) units that occur at the same elevation.

Bedrock Topography and Drift Thickness

The topography of the bedrock surface in the Villa Grove Quadrangle was important in its 3-D geologic mapping because this surface is the base of the overlying Quaternary deposits. The well and boring database was queried for wells that penetrated bedrock, and the first occurrence of bedrock within each well was selected from the database. The elevations were input into EarthVision, and a 2-D representation of the bedrock surface was created. The creation of a virtual buried surface, such as the bedrock surface, is an iterative process. Anomalous and erroneous data points were eliminated, additional points collected by drilling were added, and hand-editing of the contour lines was required (Weibel 1999). After several iterations, a reasonable representation of the bedrock surface for the Villa Grove Quadrangle was obtained.

After the bedrock topography surface was produced, the thickness of the unconsolidated deposits or drift was calculated by subtracting the virtual bedrock topography surface from the virtual land surface topography (Weibel and Abert 1999). The drift thickness data set also shows the depth to the bedrock surface from the land surface.

Three-dimensional Model of Quaternary Deposits

The 3-D models of the Quaternary materials were produced using the EarthVision software. The 3-D models were based on data from water wells, hand-augered borings, geologic test borings, engineering borings, and coal-test borings. Two approaches were used to visualize the Quaternary deposits: (1) a simplified lithologic model to show the distribution and thickness of aquifers in the drift and (2) a complete stratigraphic model.

The stratigraphic model was created by selecting the wells from the database of unit descriptions that contained detailed stratigraphic information. Lithologic units that could be interpreted as a buried soil were selected and used to create a series of 2-D grids. A buried soil horizon is indicative of older land surfaces that have been buried by subsequent deposition of younger geologic materials. To model the unconformity between the Wisconsin and Illinois glacial episodes, 36 wells were identified that contained buried soils and had unit elevations that were approximately the elevation of the suspected erosion surface. The thickness of the Wisconsin Episode deposits was derived from this calculation. To model the unconformity between the Illinois and pre-Illinois glacial episodes, 22 wells were identified and used. The thickness of the Illinois Episode deposits was calculated by subtracting this surface from the surface of the Illinois Episode. Similar techniques were used to model the contact between the Henry and Equality Formations. The 2-D surface grids were created for each of the surfaces and “stacked” in a geologic succession. The stack of surfaces created zones between surfaces that are equivalent to the volumes of geologic units. The stack of surfaces was used to refine the 3-D property model, described next.

For the simplified lithologic model, each unit in each well was assigned to one of four basic lithologic categories on the basis of the drillers’ description: coarse-grained (e.g., , sand or gravel), fine-grained (e.g., “blue clay,” till), bedrock (e.g., shale, limestone), or indeterminate (e.g., glacial drift, sandy silty). Numeric codes were assigned to these lithologic categories (fine-grained = 1, coarse-grained = 3, bedrock and indeterminate = 0). A file of the well’s identifier, x-coordinate, y-coordinate, elevations of each unit’s top and bottom (as well as at 5-foot depth intervals for units thicker than 5 feet), and the numeric lithologic code for the unit was used as input to EarthVision. To calculate the 3-D grid, the gridding algorithm used only the data points that were within a given zone, as defined by the stack of 2-D surfaces. The results of the EarthVision 3-D gridding process are 3-D contours around similar data values and between well locations. The 3-D contour with the value 2 represents the contact between fine-grained (value = 1) and coarse-grained (value = 3) units.

SPECIFIC APPLICATIONS AND CONCLUSIONS

The EarthVision models were viewed and manipulated on-screen by slicing in the x, y, or z directions or by viewing selected contour shells or intervals. The model was also vertically clipped with the EarthVision land surface and bedrock surface grids so that the materials were viewed in relation to identifiable geomorphic features, such as moraines or stream valleys. Figure 3-1 shows the 3-D stratigraphic model, as viewed from the southwest. Figure 3-2 shows pre-Illinoian age sands and gravels and their relationship to bedrock valleys, as viewed from the northeast.

The models are particularly valuable for recognizing anomalies showing unrealistic distributions of subsurface geologic units. For example, the model was modified such that sand and gravel bodies belonging to the Wisconsin, Illinois, and pre-Illinois glacial episodes would remain in their respective bundles and not be included with younger or older deposits via extrapolation using the EarthVision algorithm. Sand and gravel

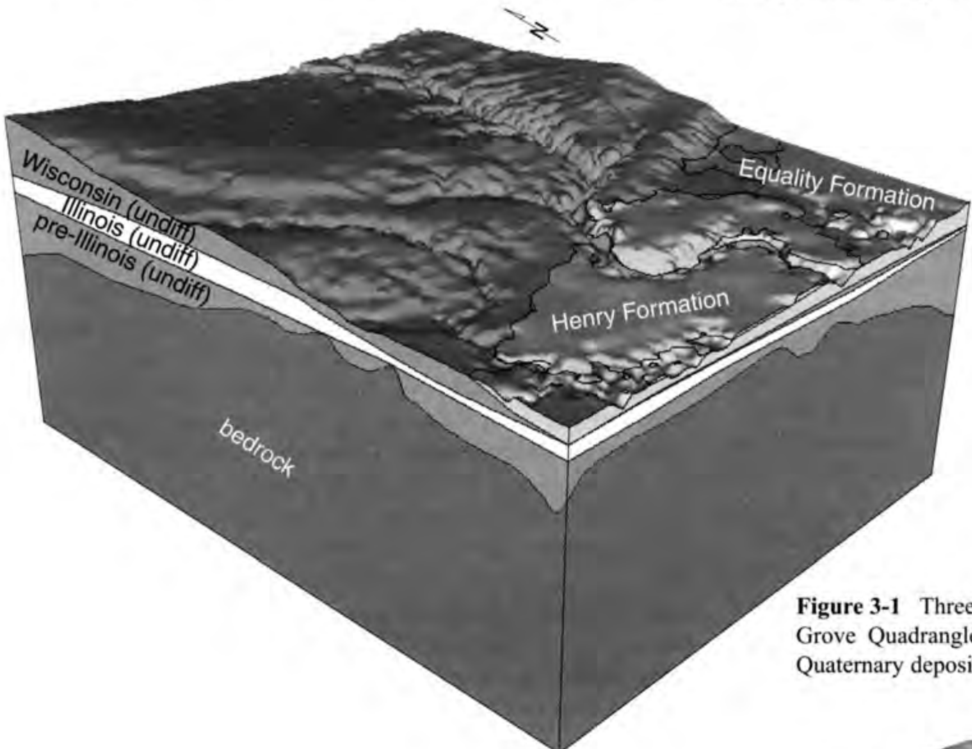


Figure 3-1 Three-dimensional stratigraphic model of the Villa Grove Quadrangle, as viewed from the southwest, showing Quaternary deposits. Vertical exaggeration: 40×.

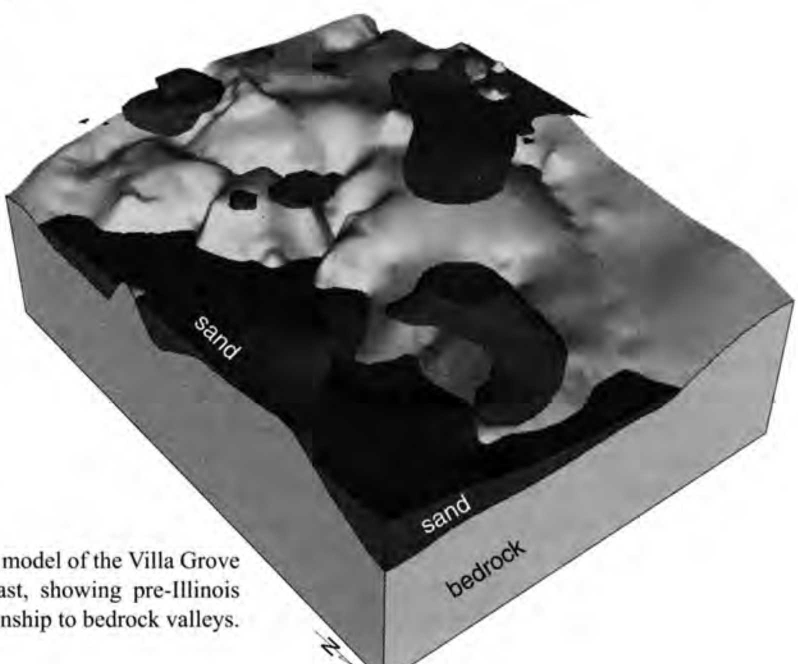


Figure 3-2 Three-dimensional lithologic model of the Villa Grove Quadrangle, as viewed from the northeast, showing pre-Illinois episode sands and gravels and their relationship to bedrock valleys. Vertical exaggeration: 40×.

was deposited independently and at different times during the three glacial episodes. It would only be a coincidence if a sand and gravel body at the base of deposits of an overlying episode was coincident with sand and gravel at the top of deposits of an underlying episode. Therefore, the distribution of sand and gravel deposits within each of the three episodes was modeled separately, and then the three bundles were re-assembled to produce the final 3-D model. It was important that final 3-D models showing distributions of subsurface units incorporated both the unbiased projected distribution of EarthVision and the logic of the geologists familiar with the geology of the quadrangle.

The models provide a user-friendly means of representing the 3-D geology so that it can be viewed from many perspectives. The models are especially effective as visualization tools for showing non-scientific audiences the relationships among geologic materials. For the geologists, such models are invaluable tools for understanding the geologic history of the quadrangle and in making derivative maps. For example, depth slice maps or slice maps that remove overlying stratigraphic units are useful to well drillers and planners because these maps show the depth of a given geologic unit beneath land surface. Elevation slices, which show the geologic materials within a given elevation interval (e.g., 850 to 800 feet above sea level), are particularly useful in modeling flat to gently sloping Quaternary deposits.

REFERENCES

Dynamic Graphics, Inc., 1997, EarthVision® user's guide 5.0: Alameda, California, Dynamic Graphics, Inc., v. 1, various paginations.

Environmental Systems Research Institute, Inc., 1994, Understanding GIS—The ARC/INFO method: Redlands, California, Environmental Systems Research Institute, Inc., various paginations.

Weibel, C.P., 1999, Topographic map of the bedrock surface, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-BT, scale 1:24,000.

Weibel, C.P., and C.C. Abert, 1999, Drift thickness map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-DT, scale 1:24,000.

Chapter 4

Remote Sensing Inputs to Geologic Mapping

Donald E. Luman

Geologists use a variety of maps to assist in interpreting and representing characteristics of the land surface. Although maps can convey many types of information, they represent selected aspects of the landscape in a generalized manner. In contrast, image-based maps provide an ungeneralized representation of landscapes on a planimetrically accurate base map. The usefulness of aerial images for mapping geologic features has long been recognized (USGS 1994).

Satellite imagery has had only limited use for geologic mapping in Illinois because of a combination of factors including (1) predominance of agricultural land use that obscures surface features; (2) prevalence of extensive and, in many locations, thick glacial deposits; (3) spatial resolution considerations; and (4) availability and cost of imagery. Despite these factors, carefully selected satellite imagery (fig. 4-1) can provide vivid images of the regional, surficial geologic features of midwestern glaciated landscapes. Although agricultural lands obscure surficial geologic features during much of the year, during the late winter and early spring and under optimal drainage conditions, remote sensing imagery can detect subtle changes in the uppermost few feet of geologic materials that directly relate to surficial processes.

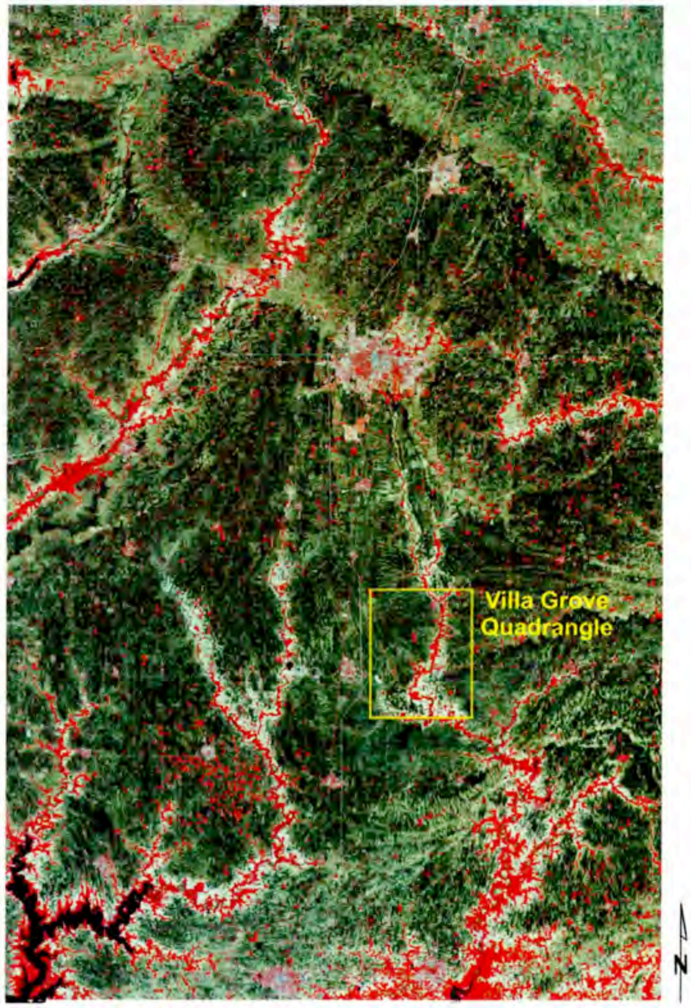


Figure 4-1 Color infrared satellite view of east-central Illinois. Champaign-Urbana is the prominent urban area in the upper center of the image. Glacial end moraines appear as lighter toned, arcuate patterns at the top of the image, which indicate lighter colored, somewhat drier soils. (Landsat 1 MSS [Multispectral Scanner] image acquired on June 11, 1978; Scene ID-LM2024032007816290). Scale 1:40,000.

DIGITAL ORTHOPHOTOGRAPHY

One inexpensive source of digital imagery is the U.S. Geological Survey's (USGS) digital orthophoto quadrangle (DOQ) products. Presently, imagery for 90+% of the conterminous United States is either contracted or already available. DOQs are coincident with the USGS 7.5-minute quadrangle map coverage, have been geometrically corrected to conform to a standard cartographic map projection, and possess a 1-meter × 1-meter ground spatial resolution (USGS 1991). Black-and-white (B&W) or color infrared (CIR),1:40,000 (nominal) scale, National Aerial Photography Program (NAPP) and NAPP-like aerial photography are the primary imagery sources used in the production of DOQs. Approximately 10% of the DOQs currently available or in production are being developed from CIR source aerial photography; the remaining 90% use B&W source aerial photography.

Orthophotography combines the image characteristics of an aerial photograph with the geometric qualities of a map. Unlike a typical aerial photograph, distortions caused by relief displacement (e.g., hills, stream valleys, buildings), camera lens, and aircraft altitude are eliminated so that all ground features are shown in their correct positions. This adjustment makes possible a true image map, which permits direct measurement of distance, areas, and angles and accurately shows the positions of ground features that are almost always omitted or generalized on traditional maps. When available in digital format, orthophotography provides a planimetrically accurate base map on which additional spatial information can be readily incorporated using geographic information system (GIS) software.

Because they are produced from recent NAPP aerial photography, USGS DOQs are generally more up-to-date representations of cultural and physical features than are the published USGS 7.5-minute quadrangle maps, especially within

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

Table 4-1 Status of USGS 7.5-minute quadrangle maps for Illinois.

Publication date	Quads (no.)	Quads (%)
1987–1997	205	19
1977–1986	421	39
1967–1976	256	24
1957–1966	160	15
1947–1956	29	3
Total	1,071	100

geographic areas that are experiencing rapid urbanization or mining activities. For example, table 4-1 shows that in Illinois 42% of the state's USGS 7.5-minute quadrangle maps were published more than 25 years ago.

In contrast, Illinois' NAPP 3 aerial photography was acquired in 1998–1999, and, at the date of this writing, almost all of Illinois' USGS DOQs are now available. Although the prioritization and funding for the update and revision of Illinois' USGS 7.5-minute quadrangle base data will continue to be problematic for many years, the use of DOQs as a surrogate for up-to-date base maps is an affordable alternative available to many states, especially given the federal cost-sharing incentives available for statewide DOQ production.

METHODOLOGY

Integrating DOQs into Geologic Mapping

Although B&W aerial photography has long been used as the standard for geologic interpretation, most applications based on natural resources are improved by using color and, especially, CIR photography. Therefore, CIR photography was used for the Villa Grove Quadrangle mapping program. The use of color is important because the human eye can discriminate many more shades of color than of gray tints, and the interpretation of color on standard color aerial photography more closely mimics human experience in everyday interpretation of the environment. Standard color photography records the "visible" portion of the electromagnetic energy spectrum on three separate layers or emulsions sensitized to blue, green, and red wavelengths (approximately 400 to 700 nanometers), which is the same reflected radiation perceived by the human eye. In CIR photography, however, the blue-sensitized layer has been eliminated, and the range of sensitivity has been extended into the "invisible," reflected near-infrared range by the addition of an emulsion sensitive to 700 to 900 nanometers.

The use of CIR photography significantly enhanced the discrimination of the following landscape features on the Villa Grove Quadrangle:

- Soil moisture gradients across parent material boundaries are better delineated because the near-infrared emulsion is quite sensitive to changes in surface moisture conditions.
- Changes in surface color, principally controlled by the green and red emulsions, are emphasized with the addition of the near-infrared emulsion.
- Water conditions at the surface, such as turbidity and the presence of chemicals or vegetation, are easily distinguished.
- Differences in the types and relative vigor of vegetation, in direct response to the cell structure type and condition, are detectable in the near-infrared portion of the electromagnetic spectrum.

Because the emulsion response of CIR photography has been shifted into the longer wavelengths to include the near-infrared, CIR photography does not record colors in the environment as they would be seen with normal color photography. For this reason, CIR photography is often referred to as "false color."

In 1996, the Illinois State Geological Survey (ISGS) began the Illinois Geologic Mapping Program (IGMaP). One of the primary objectives for the program is to derive GIS-based maps and ancillary data for a wide variety of geologic factors for each of the state's 1,071 USGS 7.5-minute quadrangles by the year 2025. The USGS 7.5-minute quadrangles of Villa Grove, Illinois, and Vincennes, Indiana-Illinois, were selected as original IGMaP pilot projects. As one of the IGMaP base data components, DOQs were produced for these two quadrangle areas based upon 1988 NAPP 1 CIR aerial photography (Luman and Hansel 1999, Luman and Barnhardt 2000).

Because of their high level of feature detail, DOQ-based reconnaissance maps produced at scales of 1 inch on the map = 1,000 feet on the ground and 1 inch = 500 feet (1:12,000 and 1:6,000, respectively) were especially useful for conducting tasks such as verifying wells, documenting outcrop locations, guiding field traverses, and interpreting surficial geologic mapping. When selected USGS digital line graph feature data were incorporated on the DOQs, the resulting maps were an excellent base for geologic mapping. Based on the experimental use of this new base map for the Villa Grove and Vincennes Quadrangles, ISGS field geologists are adopting these maps as supplements to, and sometimes replacements for, the published USGS 7.5-minute topographic quadrangle maps.

Processing Considerations Involving Image Data

Because CIR aerial photography was used for the production of the DOQ for the Villa Grove Quadrangle, a three-band image data set resulted; each band represented the spectral information for a green, red, and near-infrared wavelength band. Because of the large file size (approximately 500 megabytes), specialized image-processing procedures were used to transform the original 1-meter × 1-meter ground resolution cells (grc) to a 2-meter × 2-meter grc, reducing the DOQ image data set to one-quarter of the original file size. The resampling was deemed appropriate because the spatial dimension of ground features being represented on 1 inch = 1,000 feet to 1 inch = 2,000 feet (1:12,000 to 1:24,000) map products exceeds 1 meter × 1 meter, and therefore the high spatial resolution is not necessary. This resampling procedure was also imposed on the B&W, single-band DOQs, reducing the DOQ file size from approximately 165 megabytes to slightly more than 40 megabytes. Only when 1 inch = 500 feet scale (1:6,000) image maps are being prepared for field reconnaissance of portions of the quadrangle map is it necessary to use the original 1-meter × 1-meter grc DOQ for map compilation and printing.

Subsequent to the resampling, the reflectance (brightness) values contained in the three-band, CIR-based DOQs were transformed to a single thematic layer of information that can be used to directly interpret surficial geologic conditions within the study area. Using the three spectral bands as input variables, multivariate clustering and image classification routines (Campbell 1987) produced a spectral map representing 100 statistically separable, "spectral" classes of information. In traditional applications of image classification, a large number of spectral classes are typically generalized to several known information classes through field checks and/or direct inspection of large-scale aerial photography. In contrast, the generalization of spectral classes was minimized in the creation of the DOQ "spectral image maps" to ensure that subtle geologic features were preserved. Comparison of the resulting spectral image maps with the original, unprocessed DOQ image data revealed little or no difference in information content. This final transformation further reduced the file size of the CIR-based DOQs to approximately 10% of the original, 1-meter × 1-meter grc DOQ to less than 50 megabytes. This hybrid approach facilitated the use of such imagery as an additional component in the large-scale, geologic mapping of the Villa Grove Quadrangle and provided a template for mapping other 1:24,000-scale quadrangles in the state.

INTERPRETING SURFACE GEOLOGY WITH DIGITAL ORTHOPHOTOGRAPHY

The digital orthophotography prepared for the Villa Grove Quadrangle demonstrates how such imagery can aid the interpretation of surficial geology. In figure 4-2, the red areas labeled 1 are wheat or oats maturing during the early spring; red areas labeled 2 include lawns, pastureland, and open space. Their prominent spectral response obscures the underlying soil surface and prohibits any interpretation of surficial geology. Acquiring CIR photography during the late winter or very early spring in the Midwest can minimize the influence of this spectral response. The dark red areas labeled 3 are a mixture of woody material and the emerging leaf canopy associated with a lowland, deciduous forest along the Embarras River. This red color increases in brightness as the leaf canopy matures through the spring and summer.

The areas labeled as 4 are surface water of the Embarras River, and the black color indicates little or no turbidity or

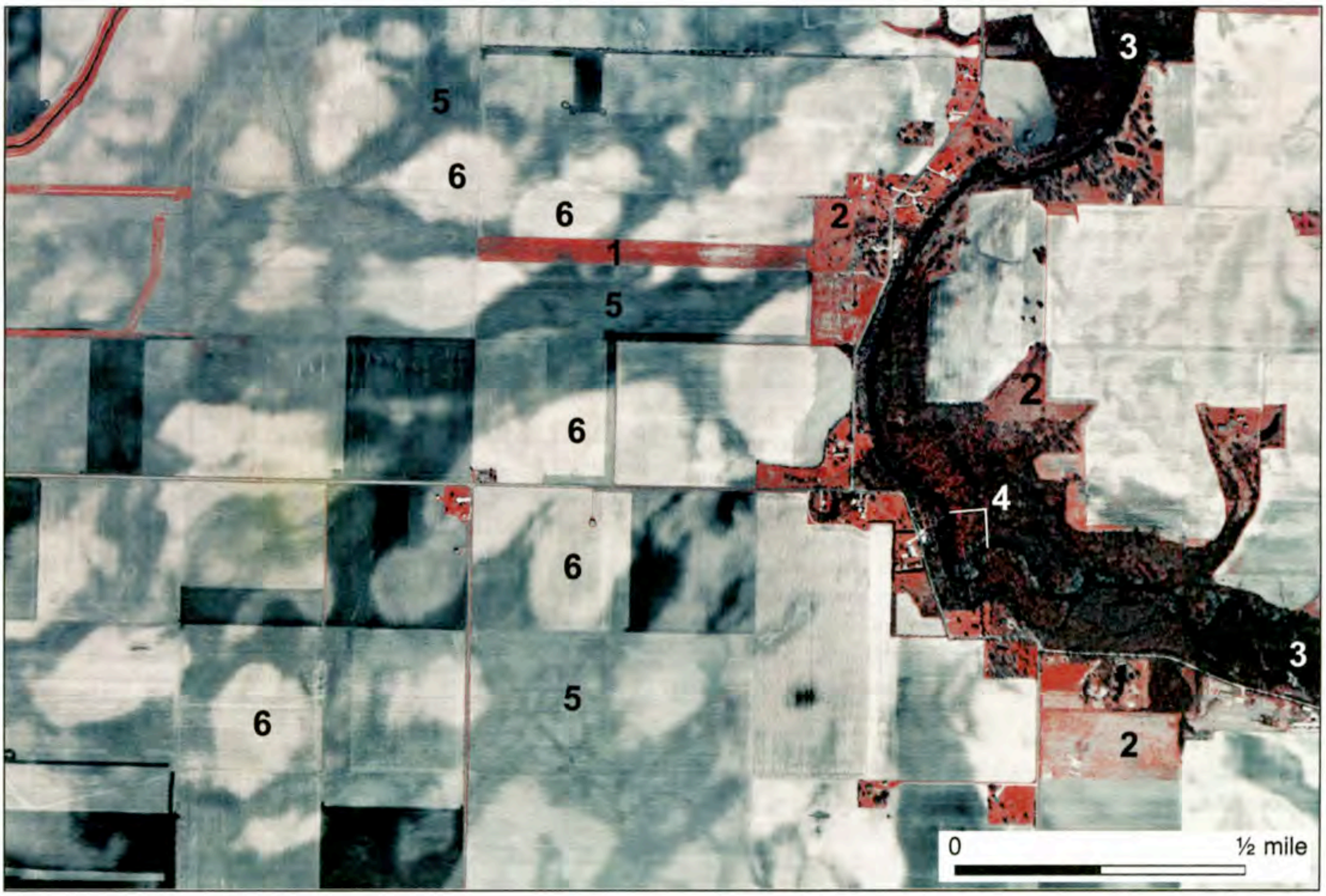


Figure 4-2 Portion of the Villa Grove digital orthophoto image map. See text for additional details. Scale 1:24,000.

vegetative matter in the uppermost part of the water column. The dark bluish green areas labeled 5 are exposed, saturated soil surfaces that include medium- and fine-textured lake sediments associated with glacial Lake Douglas. In contrast, the light areas labeled 6 were better drained surfaces associated with deltaic sand. These oval-shaped areas are also topographically higher than the surrounding bluish green lake sediments. When used in conjunction with other information such as soil survey data in a GIS, CIR photography was an invaluable asset in determining the subtle boundaries between some of the geologic materials on the Villa Grove Quadrangle (Hansel et al. 1999; see also Chapter 11).

REFERENCES

Campbell, J.B., 1987, Introduction to remote sensing: New York, The Guilford Press, 551 p.

Hansel, A.K., R.C. Berg, and C.C. Abert, 1999, Surficial geology map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey: IGQ Villa Grove-SG, scale 1:24,000.

Luman, D.E., and A.K. Hansel, 1999, Digital orthophoto image map, Villa Grove, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-OI, scale 1:24,000.

Luman, D.E., and M.L. Barnhardt, 2000, Digital orthophoto image map, Vincennes Quadrangle, Knox County, Indiana, and Lawrence County, Illinois: Illinois State Geological Survey, IGQ Vincennes-OI, scale 1:24,000.

U S. Geological Survey, 1991, Standards for 1:12,000-scale orthophoto quarter-quadrangles: National Mapping Program technical instructions, 18 p.

U.S. Geological Survey, 1994, Airborne remote sensing for geology and the environment—Present and future, *in* K. Watson and D.H. Knepper, eds., USGS Bulletin 1926, 43 p.

Basic Mapping

Chapter 5

Introduction to Basic Bedrock and Quaternary Mapping

Richard C. Berg and Zakaria Lasemi

The seven chapters in this section report on the geologic framework of the Villa Grove Quadrangle, beginning with a discussion of west-east and north-south structural cross sections followed by discussions of the rocks of the Silurian, Devonian-Mississippian, and Pennsylvanian Systems and ending with discussions of Quaternary sediments, drift thickness, and bedrock topography. The geologists relied on

- data on file at the Illinois State Geological Survey (ISGS) as discussed by Lecouris in Chapter 2
- ISGS cores and quarry exposures
- a thorough review of the scientific literature
- consistent stratigraphic nomenclature
- compilation of regional databases (to help understand geologic conditions on the quadrangle)
- regional geologic history and its potential impacts on the quadrangle
- delineation (thickness and distribution) of significant geologic units (e.g., aquifers, coal and oil-bearing rocks)
- delineation of regional structural features
- depositional models

To map the Villa Grove Quadrangle, the quality and quantity of the available geologic information needed to be assessed first, paying particular attention to identifying gaps in the data for the quadrangle. It was essential to (1) have accurate base maps; (2) obtain all digital data and convert them to a standard form; (3) digitize selected maps; (4) rescale, overlay, and plot field worksheets and raw data maps; and (5) plan the field program. Existing information was supplemented or verified with new data obtained by drilling and field mapping, both of which included sampling, describing, testing, analyzing, dating, processing, and modeling. After new data were integrated with existing data, Villa Grove map production proceeded. Those production steps involved synthesizing and interpreting all data, compiling maps and writing reports, archiving data and collections, preparing map products, and maintaining an information system amenable to continual updating.

All maps and supplemental reports needed to include a detailed explanation and legend, a stratigraphic column and description of map units, and sufficient text on methods, geologic history, environmental considerations, economic geology, structural geology, and other appropriate topics. Some of the maps and data are first appearing in this volume, whereas others have been previously published as 1:24,000-scale maps in the ISGS Illinois Geological Quadrangle series.

Certain approaches are common to geologic mapping for both Quaternary sediments and bedrock materials. Geologic maps of Quaternary sediments show the horizontal and vertical distribution of glacial and postglacial sediments that overlie the bedrock. A bedrock geologic map shows the horizontal and vertical distribution of consolidated earth materials that lie buried beneath the younger Quaternary materials throughout most of Illinois. A principal difference between bedrock and Quaternary mapping is that structural deformation, rarely observed in glacial and postglacial sediments, is a key component of bedrock geology.

For the comprehensive 1:24,000-scale Villa Grove Quadrangle mapping project described in this report, Quaternary and bedrock materials were mapped separately. Our detailed mapping effort was undertaken to develop a comprehensive geologic model of the quadrangle. From this model, an atlas of maps was produced. Basic maps represent the fundamental geology of the quadrangle, and derivative maps interpret the geology in a readily understood way for specific land use, environmental, or resource purposes.

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

Chapter 6

Bedrock Cross Sections

Michael L. Sargent

On the basis of geological information compiled from many well records (tables 6-1 and 6-2), structural cross sections (figs. 6-1 and 6-2) were constructed to show important bedrock structures within and adjacent to the Villa Grove Quadrangle (fig. 6-3). These sections also show the general stratigraphic succession for the quadrangle. These sections were vertically exaggerated 10× in order to show subtle changes in stratigraphic thicknesses and minor structural features.

The west-east cross section (fig. 6-1), which nearly parallels U.S. Route 36, was begun approximately 5 miles west of the Villa Grove Quadrangle to show the structure of the Tuscola Anticline. This strongly asymmetrical anticline crests near the western edge of the quadrangle at the position of this section. South of Route 36, the axis of the anticline trends north to south but changes orientation to approximately N10ºW north of Route 36 and crosses the western boundary into the Tuscola Quadrangle about 1 mile north of Route 36.

The north-south cross section (fig. 6-2) begins approximately 2,000 feet north of the central part of the quadrangle, trends southeast to a well near the Villa Grove water tower, and then follows the general trend of the Embarras River to a well about 1,000 feet south of the quadrangle. At the intersection with the west-east cross section, just west of the village of Camargo, there are two wells in common to both sections, those with county numbers 804 and 18. The north-south section is intended to show structural and stratigraphic features along a line that roughly parallels the axis of the Tuscola Anticline. Wells used for this section are generally about 4 to 6 miles east of the axis of the anticline. Some of the subtle structures shown in these sections, especially the north-south section, are created by the slightly zig-zag pattern of the wells. Wells closer to the axis of the anticline are structurally higher than those that are farther from the axis and thus cause most of the apparent small flexures shown in the north-south cross section.

STRUCTURE

The Tuscola Anticline, which appears dramatically on the west-east cross section, is a part of the La Salle Anticlinorium, which extends about 240 miles from central Lee County to south-central Lawrence County. The Tuscola Anticline is by far the most significant structure in the Villa Grove region. Near the crest of the Tuscola Anticline, in Sec. 36, T16N, R8E, the top of the Middle Devonian limestone is approximately 600 feet above sea level. This easily recognized stratigraphic horizon plunges approximately 2,300 feet to a depth of 1,700 feet below sea level west of the anticline. On the steeper west limb of this strongly asymmetrical anticline, the top of the Middle Devonian drops at least 1,000 feet in a horizontal distance of about 2,000 feet, indicating a true westward dip of 25º to 30º. The wells at the west end of the section indicate that the top of the Middle Devonian is virtually flat a short distance from this steeply dipping west limb. At the crest of the anticline is a broad area more than a mile wide where the strata are nearly horizontal before the structure dips both east and west.

To the east of the horizontal strata on the anticline's crest, the dips steepen to a maximum of nearly 300 feet per mile, which is about 3º to 3.5º of the eastward dip, before encountering a small syncline and secondary anticline. Near the center of the quadrangle, about where the Embarras River crosses U.S. Route 36, a small synclinal structure is followed on the east by a small anticline that crests in western Camargo on the east limb of the Tuscola Anticline. This secondary structure causes the top of the Middle Devonian limestone to rise 50 to 100 feet in the line of section before resuming the eastward dip of approximately 100 vertical feet in 4,000 horizontal feet, a dip of 1º to 1.5º east. Insufficient data are available from wells in this area to confirm the orientation of this secondary structure; it is, however, most probably parallel or sub-parallel to the Tuscola Anticline.

The north-south cross section is more difficult to interpret. It was drawn to emphasize statigraphic changes more than structure. Because wells are not available to make this well-to-well section straight along the strike of the strata, some observed structure is apparent dip. These apparent dips are a manifestation of the line of the section going slightly up and down the eastward dip of the east limb of the Tuscola Anticline. The dip at the north end of the section is principally because of the southeast trend of the section away from the crest of the Tuscola Anticline. This orientation is 25º to 40º from the strike of these strata. The minor syncline suggested in the north half of the section is created by the excursion of the line of section eastward (downdip) and westward (updip) on the east-dipping limb of the Tuscola Anticline. The paired syncline and anticline that are about two-thirds from the north end of the section is the same pair as seen on the west-east section but connected to different wells north and south of the two common wells, which are in the southeastern part of Sec. 33 and west-central part of Sec. 34, T16N, R9E. The axis of this anticline, which crests in the western part of Sec. 34, apparently trends west of north. Wells to the north, northeast, and east of this structurally high well show that there are no significant deviations from the observed eastward dip of this limb of the Tuscola Anticline.

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

Table 6-1 Location of wells used for west-east structural cross section (fig. 6-1).

Well no.	County no.	Location (Douglas Co.)	Elevation (feet)	Total depth (feet)
1	1047	430 NL, 1,135 WL Sec. 31, T16N, R8E	708 KB[1]	5,524
2	927	NW, NE, NW Sec. 32, T16N, R8E	681 GL[1]	2,524
3	58	200 SL, 50 EL SW, NW Sec. 34, T16N, R8E	654 GL	780
4	797	1,700 SL, 2,070 EL Sec. 34, T16N, R8E	656 GL	692
5	972	50 SL, 590 WL Sec. 35, T16N, R8E	648 GL	870
6	969	70 SL, 1,275 EL Sec. 35, T16N, R8E	648 GL	975
7	799	SW, SW, SW Sec. 36, T16N, R8E	646 GL	4,151
8	974	45 SL, 2,200 EL Sec. 36, T16N, R8E	649 GL	970
9	644	63 SL, 645 EL Sec. 36, T16N, R8E	660 GL	225
10	975	70 NL, 2,309 WL Sec. Irr. 5, T15N, R9E	658 GL	915
11	651	65 SL, 356 EL SW, SW Sec. 32, T16N, R9E	662 GL	436
12	806	SW, SW Sec. 33, T16N, R9E	665 GL	1,697
13	804	155 SL, 1,143 EL Sec. 33, T16N, R9E	654 GL	630
14	18	330 NL, 330 EL NW, SW Sec. 34, T16N, R9E	653 GL	527
15	19	SW, SE, NW Sec. 36, T16N, R9E	672 GL	818

[1]KB, Kelly bushing; GL, ground level.

STRATIGRAPHY

These cross sections also show stratigraphic variation. All logs used in constructing the cross sections for the Villa Grove Quadrangle area were obtained from the Geological Records Unit of the Illinois State Geological Survey. No new sample studies were undertaken. Several logs and sample studies were interpreted or reinterpreted, principally in the parts of wells where the New Albany Shale is overlain by the Borden Siltstone or Pennsylvanian rocks. Much of the generalized stratigraphic information herein is from the *Handbook of Illinois Stratigraphy* (Willman et al. 1975).

Facies changes are generally too subtle and take place over too great a distance to be detected at the scale of these sections, so thickness variation is the main stratigraphic feature shown. Strata below the upper part of the Middle Ordovician Galena Group are penetrated by wells 1, 7, and 12 (table 6-1; fig 6-1) in the west-east cross section and wells 12 and 13 (table 6-2; fig. 6-2) in the north-south cross section, which is insufficient to show facies changes. Only one boring penetrates the top of the Upper Cambrian Mount Simon Sandstone on the west-east section; none penetrates on the north-south section. The north-south section shows the strata only through the Middle Ordovician Joachim Dolomite, which is the oldest unit penetrated by any of the borings used in this section. The west-east section is projected to the Precambrian crystalline rocks using a Mount Simon thickness inferred from outside the Villa Grove Quadrangle. The nearest wells to penetrate the complete sedimentary section were drilled more than 60 miles to the southwest and nearly 90 miles

Table 6-2 Location of wells used for north-south structural cross section (fig. 6-2).

Well no.	County no.	Location (Douglas Co. except as noted)	Elevation (feet)	Total depth (feet)
1	307	SE, SW Sec. 33, T17N, R9E Champaign Co.	652 GL[1]	810
2	802	330 NL, 50 EL Sec. 10, T16N, R9E	653 GL[1]	627
3	16	SE, NE, SW Sec. 11, T16N, R9E	653 GL	1,042
4	508	442 NL, 380 WL SE Sec. 14, T16N, R9E	646 GL	702
5	528	460 SL, 330 EL NE, NW Sec. 23, T16N, R9E	663 GL	683
6	713	SE, SW, NW Sec. 23, T16N, R9E	663 GL	1,200
7	376	SE, SW, NE Sec. 27, T16N, R9E	660 KB	781
8	898	493 NL, 330 WL NE, SW Sec. 27, T16N,	676 GL	747
9	473	NE, NE, NE Sec. 34, T16N, R9E	670 GL	754
10	18	NE, NW, SW Sec. 34, T16N, R9E	653 GL	527
11	804	155 SL, 1,143 EL Sec. 33, T16N, R9E	654 GL	630
12	246	SE, NW, NW Sec. 10, T15N, R9E	647 GL	1,626
13	249	SW, SW, NW Sec. 14, T15N, R9E	634 KB	2,337

[1]KB, Kelly bushing; GL, ground level.

to the north-northeast. A well in northwestern Champaign County, about 30 miles to the north-northwest, penetrated 2,625 feet of Mount Simon Sandstone without reaching the underlying Precambrian crystalline rocks. That well provides the closest relevant minimum thickness for the Mount Simon, which thins southward. The Mount Simon is estimated to be approximately 2,400 feet thick in the Villa Grove Quadrangle. Overlying the Mount Simon is the Eau Claire For- mation. One well, on the crest of the Tuscola Anticline in Sec. 36, T16N, R8E, penetrates the entire Eau Claire Formation thickness of 696 feet. In the north-central area of the Tuscola Quadrangle, which is just west of the Villa Grove Quadrangle, the Eau Claire ranges up to 760 feet thick. In the Villa Grove Quadrangle, the Eau Claire consists of interbedded siltstone, fine-grained sandstone, shale, and carbonates. The siliciclastic components constitute about two-thirds of the formation, and carbonates constitute the other third. Limestone is slightly more abundant than dolomite in the carbonate fraction; the limestone to dolomite ratio is almost 3:2.

The Ironton and Galesville Sandstones overlie the Eau Claire Formation in the quadrangle. In the well on the crest of the Tuscola Anticline, their combined thickness is 95 feet. This area is near the southern limit of these sandstones. Virtually all sandstone disappears from this unit south of Douglas County, and these strata become indistinguishable from the underlying Eau Claire Formation. The Franconia Formation overlies the Ironton Sandstone. The only complete penetration on these sections is again the one at the crest of the Tuscola Anticline, where the Franconia is 265 feet thick. About 5 miles west of the Villa Grove Quadrangle, the well at the west end of the cross section penetrates about 225 feet of Franconia without reaching the Ironton Sandstone. The Franconia Formation is a mixture of glauconitic, silty, argillaceous sandstone and dolomite. The lower part of the formation is more argillaceous and shaley and is designated the Davis Shale Member. Above the Davis, the

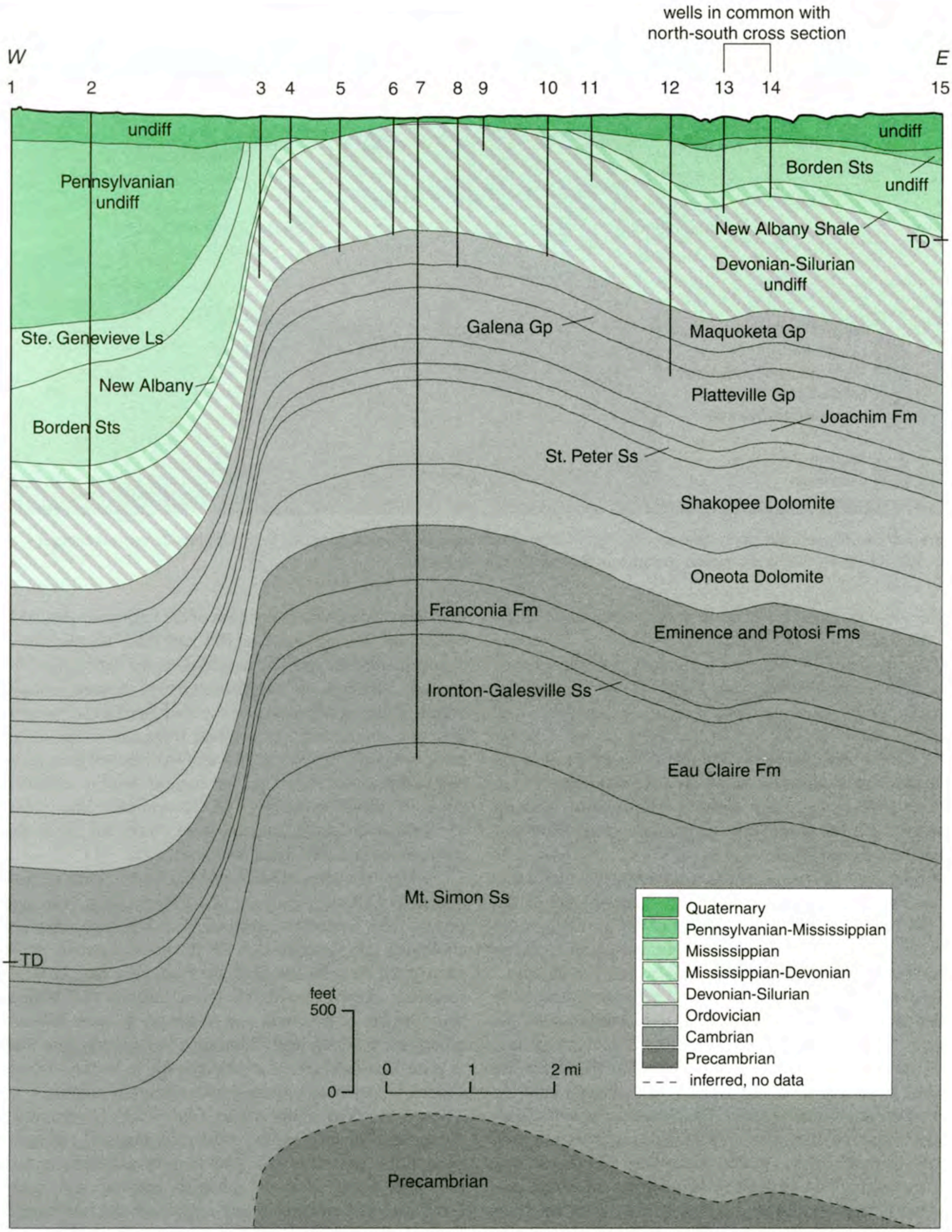


Figure 6-1 West-east structural cross section, Villa Grove Quadrangle. Well information is given in table 6-1. Vertical exaggeration: 10×. The line of the cross section is shown in figure 6-3. TD, total depth.

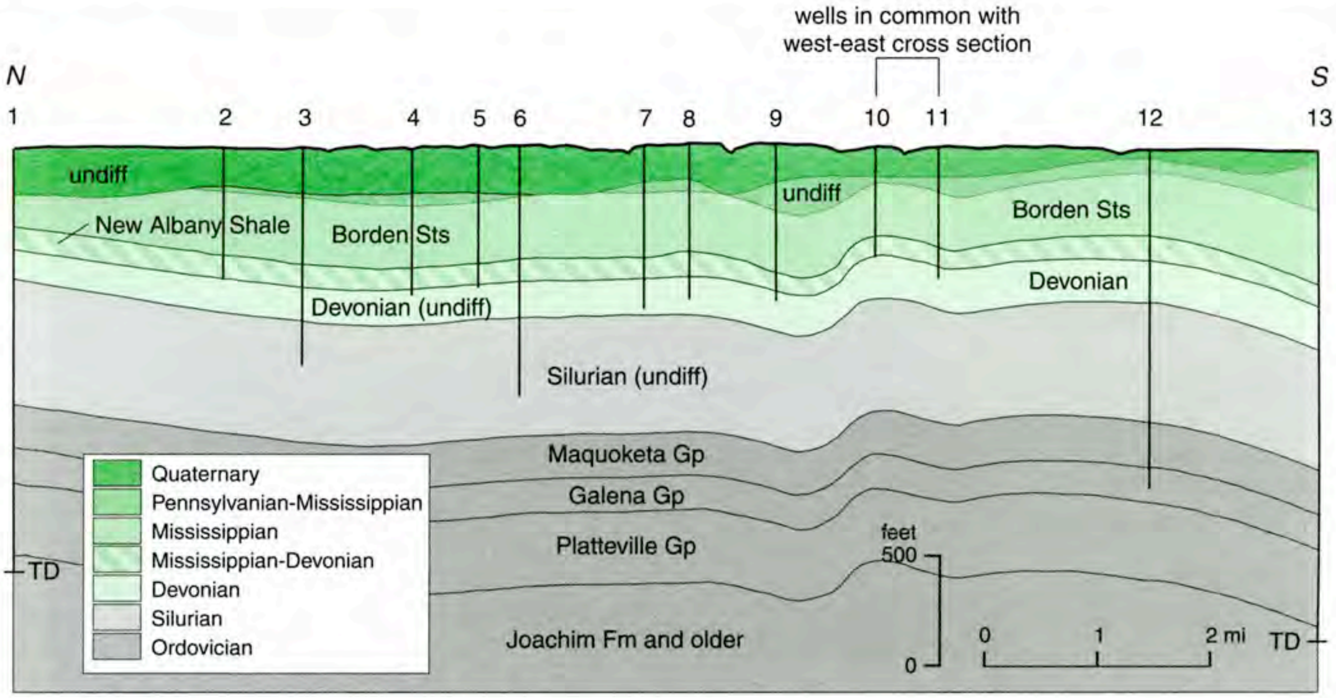


Figure 6-2 North-south structural cross section, Villa Grove Quadrangle. Well information is given in table 6-2. Vertical exaggeration: 10×. The line of the cross section is shown in figure 6-3. TD, total depth.

Derby-Doerun Dolomite Member is a silty and sandy glauconitic dolomite.

For the purposes of these cross sections, no attempt was made to differentiate the overlying Potosi Dolomite from the Eminence Dolomite, the uppermost Cambrian formations. Their combined thickness is 355 feet at the crest of the Tuscola Anticline, but the unit thickens to 384 feet at the west end of the cross section. The Potosi is a relatively pure dolomite that in most places is very vuggy and contains drusy quartz, whereas the Eminence is a sandy dolomite containing oolitic chert and thin beds of sandstone (Willman et al. 1975).

Overlying the Ordovician-Cambrian unconformity is the Oneota Dolomite. The Oneota ranges in thickness from 449 feet on the crest of the Tuscola Anticline to 352 feet at the west end of the section. The Oneota is a medium- to coarse-grained, cherty dolomite. It is commonly sandy and slightly shaley at its base.

Above the Oneota is the Lower Ordovician Shakopee Dolomite, the thickest of the Ordovician formations. The Shakopee is 541 feet thick at the crest of the Tuscola Anticline. Like the Oneota, the Shakopee thins westward to 487 feet at the west end of the section. This thickening of carbonate units on the crest of the anticline may reflect increased carbonate deposition at this location, but, with only a single cross section, it is difficult to infer the cause of this thickening. The thickening suggests that some kind of positive feature that promoted carbonate development may have existed here as early as Early Ordovician, although the principal uplift of the Tuscola Anticline occurred late in the Mississippian and in the Pennsylvanian Periods (Kolata and Nelson 1991).

Carbonate deposition during the Early Ordovician was followed by widespread deposition of the very pure quartz St. Peter Sandstone. The St. Peter is 105 feet thick on the crest of the Tuscola Anticline and 101 feet thick on the west end of the cross section. Although no significant change in sand accumulation occurred during deposition of the St. Peter Sandstone across the anticline, the succeeding Joachim Dolomite on the anticline is more than 13% thicker at 165 feet than at 146 feet at the west end of the section. The Joachim contains beds of relatively pure dolomite mixed with beds of fine-grained, sandy dolomite, argillaceous dolomite, and limestone. Chert, anhydrite, and algal dolomite domes also occur in the Joachim.

Relatively pure carbonates of the Middle Ordovician Platteville and Galena Groups occur above the Joachim. Although these groups have important differences in lithology, they are here combined into a single unit for thickness comparison. On the crest of the Tuscola Anticline, the Platteville and Galena are 477 feet thick, compared with 511 feet at the west end of the section and 536 feet at the south end of the north-south section. Both groups are predominantly limestone in this area. The Platteville is generally fine-grained to lithographic in texture, whereas the Galena is mostly a medium-grained lime grainstone.

Shaley rocks of the Upper Ordovician Maquoketa Group overlie the Galena throughout the quadrangle. The Maquoketa is about 90% shale; it is dark gray to brownish black in the lower part and lighter gray to greenish gray in the upper part. Limestone and calcareous shale compose the middle unit. The Maquoketa is fairly consistent in thickness (a little over 200 feet) throughout the Villa Grove Quadrangle, as it is in most areas of Illinois where present. It ranges from 208 feet thick at the west end of the cross section to 223 feet at the crest of

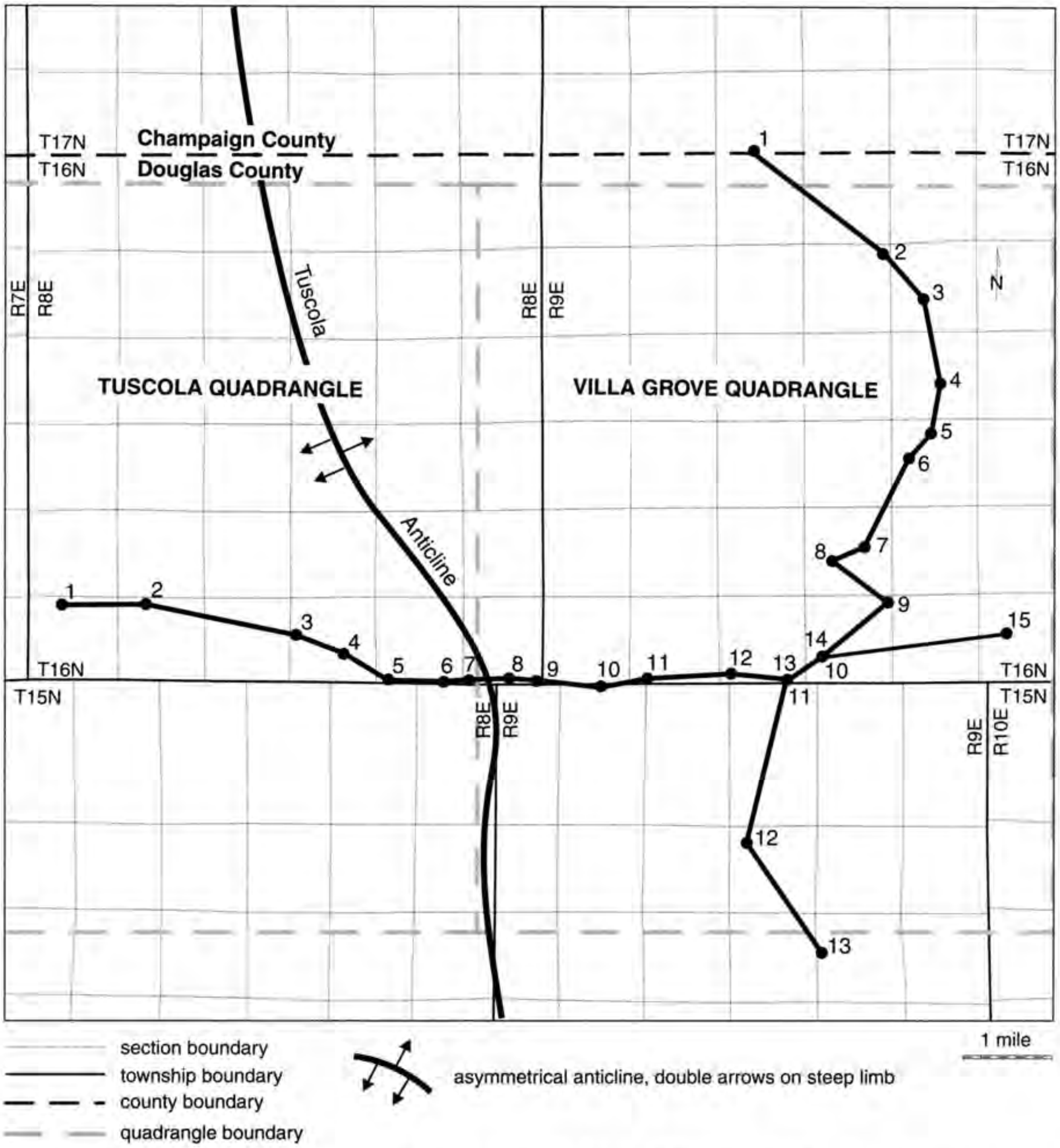


Figure 6-3 Location map for cross sections in figures 6-1 and 6-2 in the Villa Grove Quadrangle and a portion of the Tuscola Quadrangle.

the Tuscola Anticline. Less than 0.25 mile to the east, the Maquoketa has thinned to 216 feet, and about 0.25 mile farther to the east, it is 212 feet thick. Thicknesses in two wells near the south boundary of the quadrangle are 216 and 212 feet.

Silurian dolomite and argillaceous dolomite and Lower and Middle Devonian limestone, dolomite, and thinner sandy dolomite successively overlie the Maquoketa Group. Differentiating these carbonate units in some records was impossible, so they were combined in the cross sections. These carbonates are the youngest bedrock unit present, at least in part, throughout this quadrangle. A few feet of these Devonian rocks, probably 25 feet or less, have been eroded at the top of the Tuscola Anticline where the section crosses. Younger units are missing at the crest and are thinned to a feather edge on the anticline's flanks.

Numerous wells penetrate the entire Silurian through Middle Devonian section. The thickness of the combined units ranges from 685 to 706 feet across the central part of the quadrangle. To the south, these strata thicken substantially, principally because of increasing thickness of the Devonian rocks. The combined thickness of the Devonian and Silurian carbonates reaches 773 feet in the south-central part of the quadrangle. Middle Devonian limestone forms the top of the bedrock beneath the glacial drift at the top of the Tuscola Anticline in the west-central part of the quadrangle. In the west-east section, erosion-resistant Devonian limestone forms a bedrock high at the top of the anticline. Areas to the east and west that have much softer and less-resistant formations have been scoured more deeply by glacial erosion, leaving bedrock at much lower elevations and covered by much thicker glacial drift. These Silurian through Middle Devonian carbonates are being quarried by the Tuscola Stone Company about 0.5 mile south of the line of this cross section. A detailed description of these rocks is found in Chapters 7, 8, 9, and 17.

The Upper Devonian and Lower Mississippian (Kinderhookian) New Albany Shale overlies the Middle Devonian limestone except where it has been removed by erosion. The New Albany is composed of dark brown to black shales that are believed to be the source of much of the petroleum in the Illinois Basin. The unit ranges from 90 to 120 feet thick in this quadrangle, but much of this variation may be caused by difficulties in accurately picking the top of the formation where it is overlain by the Borden Siltstone, which is present almost everywhere that the New Albany occurs in this quadrangle. Where the Chouteau Limestone (also called the Rockford Limestone) is present, the top of the New Albany can be identified much more easily and with confidence. The Chouteau is absent, however, from much of the area, especially in the eastern part of the quadrangle, which makes it very difficult to distinguish the New Albany from the Borden Siltstone on some records, especially drillers' logs.

Similar problems occur in picking the top of the Borden Siltstone. The Borden is overlain by shale and siltstone of the Pennsylvanian Tradewater Formation in some areas and elsewhere by Pleistocene glacial deposits. Although these rocks can be differentiated in samples, they can be difficult to distinguish on drillers' and wireline logs. The Borden ranges from 0 to 774 feet thick. Where it is overlain by the Pennsylvanian Tradewater Formation, the Borden reaches a minimum thickness of about 250 feet in the eastern part of the quadrangle.

A thick succession of Pennsylvanian rocks occurs west of the Tuscola Anticline but, because they occur mostly west of the Villa Grove Quadrangle, are not discussed here. In the eastern and southeastern parts of the Villa Grove Quadrangle, Pennsylvanian rocks of the Tradewater and Carbondale Formations are present beneath glacial till. These rocks do not show prominently in the cross sections and are discussed in detail by Weibel and DeMaris in Chapter 10. The Pleistocene glacial deposits also are treated more thoroughly by Hansel et al. in Chapter 11.

REFERENCES

Kolata, D.R., and W.J. Nelson, 1991, Tectonic history of the Illinois Basin, *in* M.W. Leighton, D.R. Kolata, D.F. Oltz, and J.J. Eidel, eds., Interior cratonic basins: Tulsa, Oklahoma, American Association of Petroleum Geologists, Memoir 51, p. 263–285.

Chapter 7

Geology of the Silurian Rocks

Donald G. Mikulic and Joanne Kluessendorf[1]

Silurian age (~443 to 416 million years ago) rocks of the Illinois Basin are an economically important source of hydrocarbons in central and southern Illinois. Despite more than 50 years of oil production and scientific research, however, the geology of these rocks has been poorly known because they typically are deeply buried beneath younger strata and are inaccessible for direct study. (For recent summaries of the Silurian of the Illinois Basin, see Mikulic 1991 and Droste and Shaver 1987.) Only along the Tuscola Arch in Douglas County are Silurian rocks close enough to the ground surface to be accessible for study through rock coring and quarry exposures. Recent coring for the Villa Grove geologic mapping project as well as new exposures and drill cores in the Tuscola Stone Company quarry have provided an excellent opportunity to study the characteristics of these rocks and establish a reference section for the Silurian in this part of the Illinois Basin.

The primary source of information on Silurian rocks in the Villa Grove Quadrangle area is the Villa Grove deep hole-2 (VGDH-2) core (ISGS core 14845; fig. 7-1), which penetrated more than 580 feet of Silurian strata. In addition, the Tuscola quarry exposes the upper 100 feet of the Silurian section, and a few other cores and well cuttings provide supplemental data. At all sites, the Silurian is overlain unconformably by Lower Devonian rocks (Chapters 8 and 9) and underlain unconformably by Upper Ordovician strata. The following Silurian units have been recognized in this study.

SILURIAN SYSTEM

Sexton Creek Formation

The Sexton Creek Formation, which is about 20 feet thick, is the lowermost Silurian unit in the area. In the VGDH-2 core, this unit is underlain by Ordovician Maquoketa Shale, 118 feet of which was penetrated by drilling. The upper 82 feet of the Maquoketa is dark greenish gray fissile mudstone and greenish gray mudstone with thin, tan, very fine crystalline dolomite interbeds that have burrowed tops. The basal 35 feet consists of limestone with common shale partings toward the base.

Following a drop in sea level at the end of the Ordovician and a period of erosion, the Sexton Creek was deposited during the early Silurian (Llandovery) marine transgression. Clasts of underlying Ordovician mudstone are present at the base of 4 feet of algal boundstone composed of gray, crinkly laminated dolomite containing several thin zones of small phosphatic nodules. This boundstone is overlain by about 1 foot of planar-laminated, dark brown dolomite.

The upper 15 feet of the Sexton Creek is composed of bioturbated, dark brownish gray, fine to coarse crystalline dolomite, which contains scattered brownish black argillaceous partings throughout and is cherty in its upper half. This portion of the unit ranges from skeletal packstone to grainstone; fossils are represented primarily by brachiopod and pelmatozoan bioclasts and also by tabulate and rugose coral fragments. A karst surface with a blackened crust, clasts, and solution pits at the top of the Sexton Creek appears to mark a major lowering of sea level and subaerial exposure. This surface represents the top of the Alexandrian Series in the basin.

Bainbridge Group

The next youngest Silurian strata are represented by the Bainbridge Group, which is divided into four units, from top to bottom: (1) an upper reefy unit, which here is considered a facies of the Moccasin Springs Formation; the (2) Moccasin Springs proper, composed of an upper bafflestone-grainstone facies and a lower argillaceous facies, all of which is underlain by the (3) St. Clair Limestone; and the (4) Seventy-Six Shale. In the VGDH-2 core, the entire Bainbridge Group is 518 feet thick. The reefy facies of the Moccasin Springs is 140 feet thick, the bafflestone-grainstone facies 140 feet, the argillaceous facies 36 feet, the St. Clair Limestone 137 feet, and the Seventy-Six Shale 5 feet.

The Bainbridge Group is primarily Wenlock-Ludlow in age (although it could range upward into the Pridoli, considering the potential age of the overlying unnamed cherty dolomite), as determined from biostratigraphic information from superjacent and subjacent units and from outcrop areas along the edge of the basin (see Chapter 9 and Thompson 1993).

Seventy-Six Shale At the base of the Bainbridge Group, directly above the Sexton Creek Formation, is a conspicuous thin, argillaceous interval that may be equivalent to the Seventy-Six Shale of the Bainbridge Group, as defined in the Missouri portion of the Illinois Basin (Thompson 1993; in Missouri, the Seventy-Six Shale is a member of the Bainbridge Formation). The Seventy-Six Shale is only about 5 feet thick in the VGDH-2 core. Marking a marine transgression, this pinkish gray, dolomitized lime mudstone contains common greenish gray argillaceous partings. Several hardgrounds or karst surfaces are present in the lower half of the unit, whereas the upper half is bioturbated. The contact between the Seventy-Six and the underlying Sexton Creek is sharp and irregular and marks a dramatic lithologic change. Biostratigraphic work in Missouri (Thompson 1993) indicates that the Seventy-Six Shale is late Llandovery–early Wenlock in age.

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

[1]Present address: Weis Earth Science Museum, University of Wisconsin–Fox Valley, 1478 Midway Road, Menasha, WI 54952.

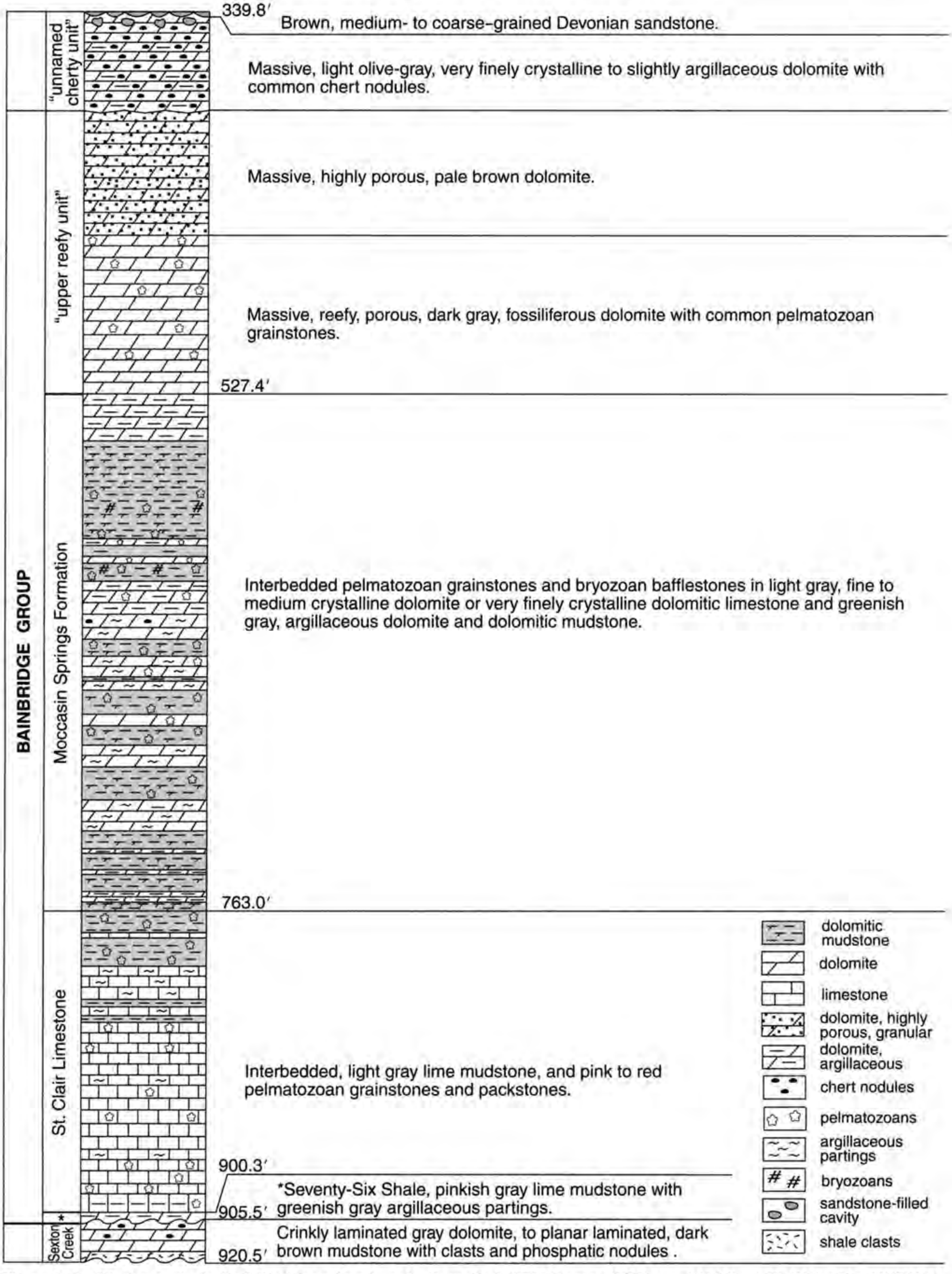


Figure 7-1 Silurian rocks in the Villa Grove Quadrangle, from the VGDH-2 core (ISGS core 14845). A.E. Kleiss No. VGDH-2, NW SW NW, Sec. 30, T16N, R9E, Douglas County.

St. Clair Limestone The St. Clair Limestone, which succeeds the Seventy-Six Shale, is composed largely of interbedded light gray to pinkish gray lime mudstone and pink to red pelmatozoan packstone and grainstone layers. This unit reaches a thickness of approximately 137 feet in the VGDH-2 core. The lower 20 feet are dominantly massive pelmatozoan grainstone. Greenish gray or reddish brown argillaceous partings, which are common throughout much of the unit, become abundant toward the top, where the St. Clair grades into the overlying Moccasin Springs.

Moccasin Springs Formation Above the St. Clair Limestone is the Moccasin Springs Formation proper, which is divided into two facies. (1) The lower argillaceous facies is characterized by greenish gray argillaceous dolomite and dolomitic mudstone interbedded with skeletal wackestone, packstone, and grainstone. In general, fossils are dominated by pelmatozoan debris. *Chondrites* burrows are locally common in the upper part of the argillaceous facies. (2) The upper bafflestone facies consists predominantly of interbedded layers of pelmatozoan grainstones and fenestrate bryozoans in light gray, fine to medium crystalline dolomite. Intervals of fenestrate bryozoan-pelmatozoan bafflestone occur in very fine crystalline, light gray dolomitic limestone with common chert nodules and argillaceous partings.

"Upper reefy unit" Overlying the Moccasion Springs proper is the upper reef facies, which is dominated by massive dark gray, porous, fossiliferous dolomite, which is overlain by pale brown, massive, highly porous dolomite. Pelmatozoan grainstones are common locally, with the cystoid *Caryocrinites* being especially conspicuous. A distinctive form of *Lichenalia* and fenestrate bryozoans are also characteristic of the reef biota. As a result of irregular reef growth, this reef facies varies greatly in thickness from 96 to 178 feet within a small geographic area. The highly irregular surface of the dark gray portion of the reef facies is draped by the brown porous portion of that facies. With a north-south length of at least 2.2 miles, it is not known whether this unit represents an individual reef body or a shelf-edge carbonate bank. In other parts of the basin, large reefs are common in the Moccasin Springs Formation (Lowenstam 1949).

"Unnamed Cherty Unit"

The uppermost Silurian strata in the Villa Grove Quadrangle consist of 55 to 83 feet of cherty dolomite. At present, this unit cannot be assigned to any known Silurian rock unit in the Illinois Basin. It would occupy a position similar to that of the Bailey Limestone, following reassignment of that unit from a Devonian to mostly Silurian age by Droste and Shaver (1987). However, reassignment of the Bailey to the Silurian remains questionable (Mikulic 1991, Norby 1991), and, other than being composed of cherty carbonates, these strata bear little similarity to the Lower Devonian Bailey in its type area. On the basis of biostratigraphic data that include conodonts of a late Ludlow or possibly early Pridoli range (Chapter 9), the age of the cherty unit in the Villa Grove area is undoubtedly Silurian. The brachiopod biota from this unit is probably Ludlow in age (A.J. Boutcot, 2000, personal communication).

Thickness of the unnamed cherty dolomite varies considerably over short distances because of both pre-Devonian erosion on its upper surface and depositional drape over the irregular surface of underlying reef facies in the Moccasin Springs Formation. The unconformable upper surface of the cherty dolomite is marked by significant irregular relief, a blackened crust in places, and small subsurface karst cavities in the upper few feet of the unit. In places, clasts of the cherty unit are present at the base of the overlying Devonian strata. Low areas on this surface and the subsurface cavities are filled with brown, medium- to coarse-grained Devonian sandstone, which is absent elsewhere. The unnamed cherty dolomite is characterized by massive, light olive-gray, very fine to fine crystalline to slightly argillaceous dolomite, which ranges from moldic skeletal mudstone to wackestone with some packstone. These strata are fossiliferous, containing a variety of brachiopods, trilobites, corals, and other taxa. Common chert nodules and abundant patches of pale brown, granular dolomite may be related to *Thalassinoides* burrows.

DEPOSITIONAL HISTORY

Near the end of the Ordovician Period, a dramatic drop in sea level occurred, and the entire Illinois Basin area became emergent (Mikulic 1991). As a result, the shales and limestones of the Maquoketa Group were subjected to intensive erosion in some areas, yielding an uneven land surface. At the beginning of the following Silurian Period (Llandovery), marine seas again flooded the area, depositing the Sexton Creek Formation. Another brief drop in sea level during the Llandovery resulted in the emergence of the Sexton Creek and the development of a prominent regional unconformity at its surface, which appears to be marked by karstification. This surface is equivalent to the top of the classical Alexandrian Series in North American stratigraphy. Re-flooding of the area is represented by the Seventy-Six Shale. Several karst or hardground surfaces in the lower half of this unit indicate periodic episodes of nondeposition. The Seventy-Six Shale grades upward into the pelmatozoan-rich limestone of the St. Clair, which represents shallow-water, normal-marine conditions with some shoaling. The limestones and shales of the Moccasin Springs represent deeper-water basinal sediments that shallow upward into a reef or carbonate bank at its top. These reefal beds, in turn, were covered by the slightly deeper-water sediments of the unnamed cherty dolomite. A major period of erosion and prolonged subaerial exposure followed another pronounced drop in sea level at the close of the Silurian. As a result, both epikarstic and subsurface karst features developed at the top of the unnamed cherty dolomite unit.

REFERENCES

Droste, J., and R.H. Shaver, 1987, Upper Silurian and Lower Devonian stratigraphy of the central Illinois Basin: Bloomington, Indiana, Indiana Geological Survey, Special Report 39, 29 p.

Lowenstam, H.A., 1949, Niagaran reefs in Illinois and their relation to oil accumulation: Illinois State Geological Survey, Report of Investigations 145, 36 p.

Mikulic, D.G., 1991, Tippecanoe II Sub-sequence—Silurian System through Lower Devonian Series, *in* M.W. Leighton, D.R. Kolata, D.F. Oltz, and J.J. Eidel, eds., Interior cratonic basins: Tulsa, Oklahoma, American Association of Petroleum Geologists, Memoir 51, p. 101–107.

Norby, R.D., 1991, Biostratigraphic zones in the Illinois Basin, *in* M.W. Leighton, D.R. Kolata, D.F. Oltz, and J.J. Eidel, eds., Interior cratonic basins: Tulsa, Oklahoma, American Association of Petroleum Geologists, Memoir 51, p. 179–194.

Thompson, T.L., 1993, Paleozoic succession in Missouri, Part 3—Silurian and Devonian Systems: Rolla, Missouri, Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigations 70, Part 3, 214 p.

Chapter 8

Devonian and Mississippian Rocks: Stratigraphy and Depositional History

Zakaria Lasemi

The Villa Grove Quadrangle is underlain by Paleozoic rock units ranging in age from the Cambrian through Pennsylvanian. This chapter describes the stratigraphy, lithology, and depositional history of the Devonian and Mississippian strata in the Villa Grove Quadrangle. Numerous boreholes penetrate the Upper Ordovician through the Middle Devonian strata in the western part of the Villa Grove Quadrangle. Data from these boreholes, rock cores (including two cores drilled for the Villa Grove mapping project), and exposures in the Tuscola Stone Company quarry have provided important information regarding the stratigraphy, depositional facies, and mineral resource potential of the Silurian and Devonian carbonates in central Illinois.

The Paleozoic bedrock throughout the Villa Grove Quadrangle is overlain by 35 to 250 feet of Quaternary sediments. The Middle Devonian limestone and dolomite subcrop beneath thin Pleistocene glacial deposits at the crest of the Tuscola Anticline in the western part of the quadrangle, just east of Tuscola. The presence of high-quality stone close to the surface here led to the development of the Tuscola quarry. East of the quarry, bedrock strata dip eastward from the crest of the anticline, and Upper Devonian and Mississippian rocks overlap the Middle Devonian (Weibel and Lasemi 2001).

Silurian and Devonian carbonates in the Villa Grove Quadrangle are important sources of construction aggregate in central Illinois. These rocks are also important aquifers for domestic and farm water supply, especially in the western part of the quadrangle. Along the east margin of the quadrangle, the Silurian and Devonian strata are deeply buried under several hundred feet of Upper Devonian, Mississippian, and Pennsylvanian siliciclastics (shale, siltstone, and sandstone) and up to 250 feet of Quaternary glacial deposits. Some of these units are also economically important because they contain petroleum source rocks (Upper Devonian–Lower Mississippian New Albany Shale), coal resources (Pennsylvanian), and groundwater aquifers (Quaternary sand and gravel and Pennsylvanian sandstone and coal). The Pennsylvanian strata in the quadrangle contain several coal beds in the southeastern portion of the quadrangle (Chapter 18), which mark the northern extent of a major coal deposit in central Illinois.

STRUCTURAL SETTING

The west flank of the Tuscola Anticline, a major structural feature along the La Salle Anticlinorium (Bell 1943, Bristol and Prescott 1968), is located in the western part of the Villa Grove Quadrangle. It is the largest anticline in Illinois in terms of closure and relief (Nelson 1995). Major uplift along the anticline apparently occurred very late in the Mississippian and early in the Pennsylvanian Period. After the Paleozoic, the crest of the anticline was eroded, which exposed Devonian rocks at the crest and Mississippian rocks on both flanks. The anticline has created hydrocarbon traps such as the Hays oil field, west of the Villa Grove Quadrangle (Bristol and Prescott 1968).

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

BEDROCK STRATIGRAPHY

Lower Devonian Series

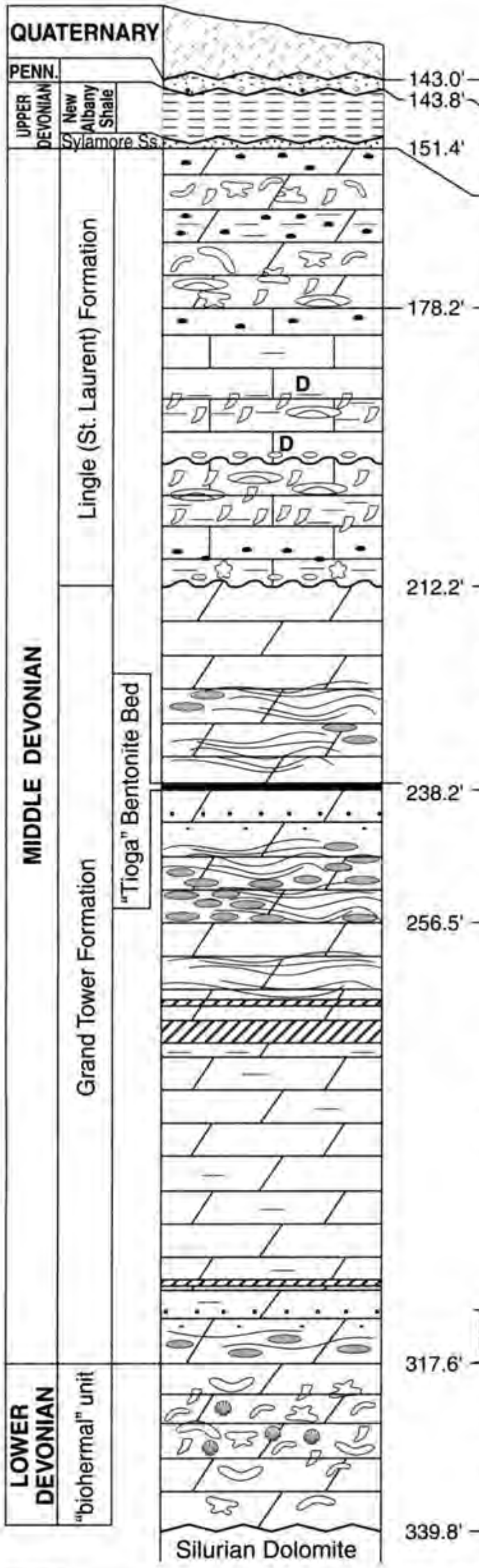
Biohermal unit A bluish gray and buff, fine to coarse crystalline dolomite that ranges between 5 and 45 feet in thickness unconformably overlies the Silurian dolomite. It is disconformably overlain by the Dutch Creek Sandstone Member of the Grand Tower Formation (fig. 8-1). We informally refer to this as yet unnamed interval as the biohermal unit. The biohermal dolomite is, for the most part, very vuggy with abundant fossil moldic porosity and, in many areas, heavily stained with oil. Recognizable fossils include large rugose corals, stromatoporoids, brachiopods, and echinoderm remains. The vuggy interval is lenticular and grades into a dense, bluish gray dolomite, which is slightly argillaceous with some shale partings and wispy laminations. The geometry and fossil content indicate that the vuggy dolomite may represent a bioherm (small patch reef). The contact between the biohermal unit and the overlying Dutch Creek Sandstone is sharp and marked by abundant vertical burrows of unknown origin.

Conodont fossils (Chapter 9) indicate that the biohermal unit is Early Devonian in age (middle Emsian) and probably equivalent in age to the Clear Creek Formation in southern Illinois. The conodont fauna in this unit is different from that recovered from type Dutch Creek Sandstone. The oldest part of the Dutch Creek, which is latest Emsian(?) to earliest Middle Devonian, is still younger than the biohermal unit (Chapter 9). The presence of Lower Devonian strata has not been reported previously from this part of the Illinois Basin.

A prominent unconformity marks the contact between the Lower Devonian Series (biohermal unit) and the underlying Silurian dolomite. This contact is undulatory and in many places contains a thin sandstone bed or lens. Quartz sands also fill the fissures common along this contact.

Middle Devonian Series

Middle Devonian Series strata in the Villa Grove Quadrangle include the Grand Tower and Lingle (St. Laurent) Formations



Diamicton, sand and gravel.

Conglomerate with lithoclasts of various sizes in a rusty red, silty clay matrix.

Shale, medium gray and chocolate brown with interbeds and mottlings of greenish gray and light olive-gray. The base is sandstone (Sylamore Sandstone), medium dark gray, pyritic.

Dolomite, medium light brownish gray to light gray, finely to coarsely crystalline, fossiliferous with vuggy and fossil moldic porosity; very fossiliferous (corals, stromatoporoids, bryozoans, etc.) and oil-stained in the lower 10 feet; cherty in the upper 13 feet; slightly oil-stained in upper 6 feet.

Limestone (grainstone and packstone with interbeds of wackestone and lime mudstone), fossiliferous with corals, stromatoporoids, bryozoans, echinoderms, etc.; cherty at top and near the base. Coral rudstone at 193.8–194.9 feet and 204.2–205.7 feet. A well-sorted, crinoidal-bryozoan grainstone occurs at 190.7–193.8 feet, which is equivalent to an oolitic interval seen at the Tuscola quarry. A prominent discontinuity surface with dark gray, phosphatic and interclastic shale at base.

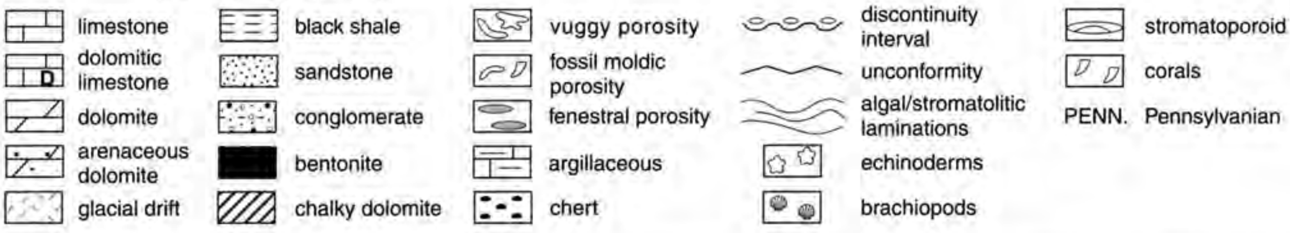
Dolomite, dominantly microcrystalline, lower part slightly sandy to sandy, in part fenestral, common stromatolitic laminations in the lower half. "Tioga" Bentonite Bed at 238.0–238.2 feet.

Dolomite, light gray-brown to tan, finely crystalline, upper one-third sandy to very sandy, which in part grades into sandstone; lower two-thirds fenesteral and laminated (stromatolites).

Dolomite, light blue-gray, light gray-tan and tan, mostly microcrystalline, in part fenestral, in part with common argillaceous partings, in part slightly sandy to very sandy, algal lamination near the base and top; white, chalky, microcrystalline dolomite at 267.1, 268.0, 270.2, and 272.7 feet. Shale, medium dark gray at 273.7–273.9 feet.

Dutch Creek Sandstone equivalent

Dolomite, buff and blue gray, fine to coarse, vuggy with abundant fossil moldic porosity, common corals, sporadic oil stains, heavily oil-stained at base. Few wispy laminations/shale partings in the lower part.



(fig. 8-1). In the Villa Grove Quadrangle, the Grand Tower consists of the Dutch Creek Sandstone Member at the base and the Tioga(?) Bentonite Bed near the top.

The Lingle consists of limestones and dolomites. For Illinois, Nelson et al. (1995) proposed abandoning the name Lingle Formation and adopting the name St. Laurent Formation, as used in southeastern Missouri, where the formation includes strata representing the Lingle and its lateral equivalent the Alto Formation (Nelson et al. 1995). North (1969) assigned all of the Lingle in east-central Illinois to the Tripp Member as defined in southern Illinois. However, there is presently not enough biostratigraphic information available to verify this conclusion. Mapping in southern Illinois has revealed that the members North (1969) defined within the Lingle are local units that, at best, can be recognized only in their immediate type areas (Nelson et al. 1995). These members cannot be reliably recognized in the outcrop area or elsewhere in the subsurface. For detailed reviews of the Devonian stratigraphy and paleogeography of the Illinois Basin, see Collinson et al. (1967), Droste and Shaver (1983), Devera and Fraunfelter (1988), and Devera and Hasenmueller (1991).

Grand Tower Formation The Grand Tower Formation (fig. 8-1) in the Villa Grove Quadrangle ranges between 30 and 105 feet in thickness. It is slightly sandy to sandy (well-rounded, fine- to medium-grained, quartz sand grains) throughout but becomes less sandy upward. Several dolomitic sandstone lenses are present in the Grand Tower, especially in the lower part.

At its base, the Grand Tower consists of the Dutch Creek Sandstone Member, which is a light yellowish gray sandstone primarily consisting of fine- to medium-grained, well-rounded, quartz sand grains. The Dutch Creek varies from a slightly dolomitic to very dolomitic sandstone and, in places, grades into a yellowish tan, fine to medium crystalline dolomite. It is mostly 0 to 10 feet thick, but can be up to 30 feet thick in some areas. In the Tuscola quarry, the Dutch Creek averages about 4 feet thick.

Apparently absent in the Villa Grove Quadrangle is the Geneva Dolomite Member, a dark brown, sucrosic dolomite that occurs above the Dutch Creek Sandstone Member and commonly produces oil in the basin (Schwalb 1955, Meents and Swann 1965).

The remainder of the Grand Tower above the Dutch Creek is a light yellowish gray to yellowish tan microcrystalline (micritic) dolomite. Its lower half contains thin beds of mottled, bluish gray, partly argillaceous, microcrystalline dolomite with scattered shale partings. Several soft, white, chalky microcrystalline dolomite beds occur in this lower half of the formation.

The upper part of the Grand Tower contains well-developed stromatolitic laminations (fig. 8-2B) formed by the trapping of sediments by blue-green algae. Some of the stromatolites seen in the Tuscola quarry form mound-shaped structures (boundstone) approximately 10 feet high. Although found throughout the Grand Tower, fenestral fabric (fig. 8-2A) is more common in this upper part, and mud cracks have been observed in quarry exposures and cores. The Tioga(?) Bentonite Bed generally occurs about 20 to 30 feet below the top of the Grand Tower (fig. 8-1) and is up to 4 inches thick in the area.

Figure 8-1 Stratigraphic column (above the Silurian) of the VGDH-2 core (ISGS core 14845), A.E. Kleiss No. VGDH-2, NW SW NW, Sec. 30, T16N, R9E, Douglas County.

Lingle (St. Laurent) Formation The Lingle Formation ranges between 0 and 70 feet in thickness in the quadrangle and consists of a limestone facies in the lower half and a dolomite facies in the upper half (fig. 8-1). In the Tuscola quarry and adjacent areas in the western part of the quadrangle, the Lingle thins to less than 25 feet and is absent in some areas because of truncation along the Tuscola Anticline.

The limestone-dominated interval of the Lingle in the Villa Grove Quadrangle consists of coral-stromatoporoid biostromes (fig. 8-2C, D), bioclastic grainstone, oolitic grainstone (fig. 8-2E), and partly cherty and argillaceous lime mudstone/wackestone. As seen in the Tuscola quarry exposure, some corals (e.g., *Hexagonaria* species) can reach up to a foot or more across.

The dolomite facies of the Lingle is variable in thickness, ranging from 15 to 35 feet thick throughout the quadrangle. It is truncated in most areas along the Tuscola Anticline. The dolomite facies (fig. 8-1) is generally characterized by (1) a fine to medium crystalline, oil-stained, vuggy dolomite in the lower part and (2) a fine crystalline, cherty, and, in part, argillaceous dolomite in the upper part. The vuggy dolomite is fossiliferous with corals, bryozoans, echinoderms, brachiopods, and rare stromatoporoids.

The contact between the Lingle Formation and the underlying Grand Tower Formation in the Villa Grove Quadrangle (and elsewhere in central Illinois) is marked by a discontinuity surface characterized by a dark gray, organic-rich shale. This shale is commonly sandy and intraclastic with abundant fish remains. Pyrite and phosphatic grains are also present at this horizon. Several discontinuity surfaces and/or hardgrounds occur at various horizons within the Lingle Formation.

Upper Devonian Series

Upper Devonian strata in the Villa Grove Quadrangle consist of the organic-rich New Albany Shale and the underlying thin, dark gray, pyritic sandstone (Sylamore Sandstone). The base of the New Albany is very pyritic and in many places contains abundant lithoclasts (some from the underlying Middle Devonian rocks), which mark the presence of an unconformity between the Middle and Upper Devonian Series. The New Albany Shale (fig. 8-1), which contains the Sweetland Creek and Grassy Creek Members and the Saverton-Hannibal Formation (about 10 feet), generally ranges from 90 feet to 110 feet thick in the quadrangle except along the crest of the Tuscola Anticline where the unit is thin or absent. The Sweetland Creek and Grassy Creek are mostly chocolate brown, organic-rich shales with some greenish gray intervals. They are the source rock for most of the oil and gas found in the Illinois Basin (Cluff et al. 1981). The Saverton Shale is a gray shale that overlies the Grassy Creek Shale. It is not differentiated in the quadrangle and is included in the Mississippian Hannibal Formation.

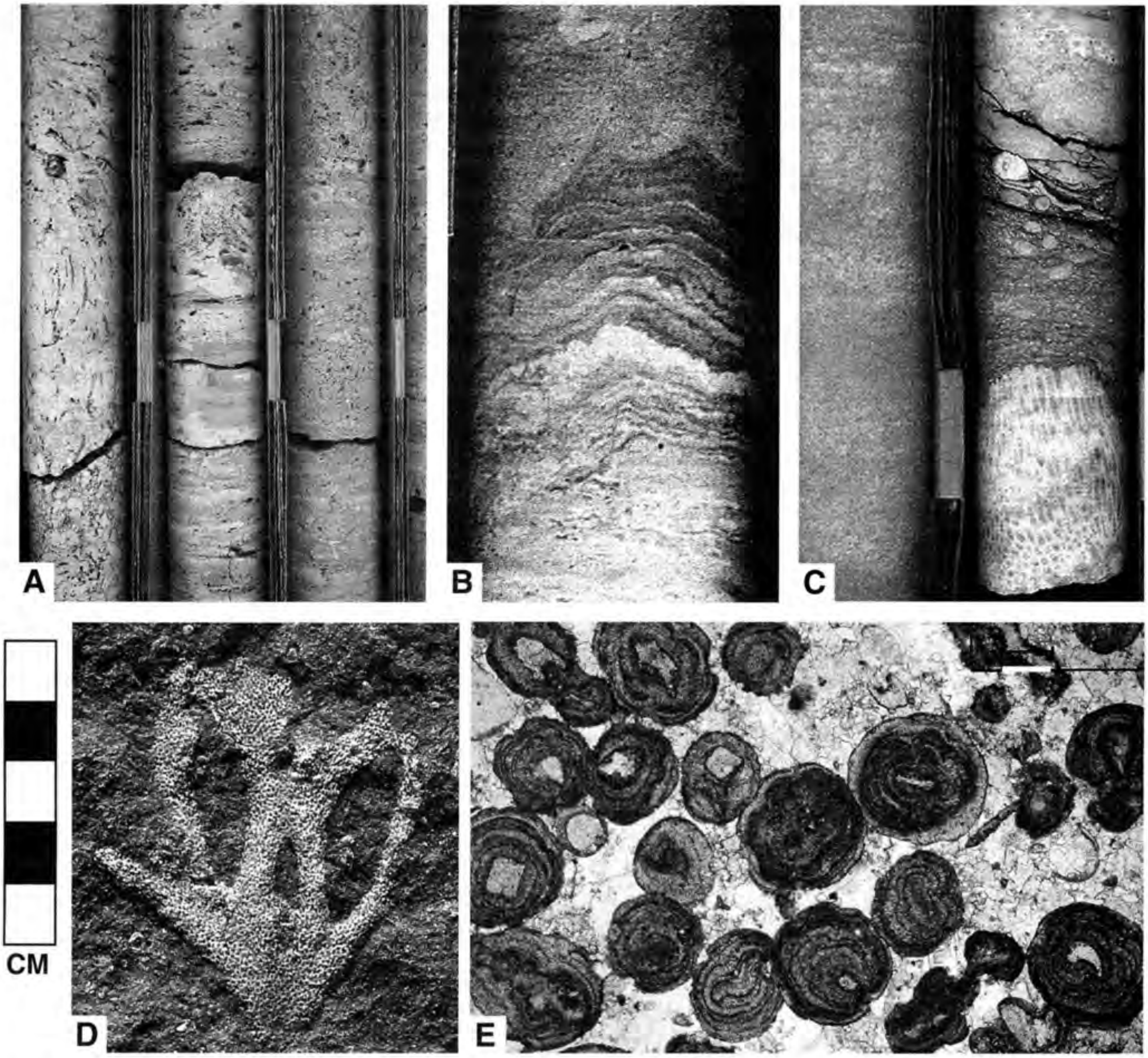


Figure 8-2 Middle Devonian carbonates in the Villa Grove Quadrangle. (A) Fenestral dolomite, Grand Tower Formation, VGDH-2 core (ISGS core 14845). (B) Stromatolitic laminations in the Grand Tower Formation, VGDH-2 core. C. A coral-rich zone in the Lingle (St. Laurent) Formation. The overlying unit (left) is a well-sorted, bioclastic grainstone, which in places grades into an oolitic limestone (see E), VGDH-2 core. (D) A coral from the Lingle (St. Laurent) Formation, Tuscola Stone Company quarry. (E) Thin-section photomicrograph of an oolitic limestone from the Lingle (St. Laurent) Formation, Tuscola Stone Company quarry; bar scale = 0.5 mm. Core sections in C, D, and E are 1.75 inches wide. Core location is given in figure 8-1.

Mississippian System

The oldest Mississippian units in the Villa Grove Quadrangle are the Kinderhookian Hannibal Shale and Chouteau Limestone. The Hannibal is a light gray to light greenish gray shale that is generally thinner than 10 feet in the quadrangle. It is indistinquishable from the Upper Devonian Saverton Shale in the quadrangle. The Chouteau Limestone, which overlies the Saverton-Hannibal Shale, is a light gray, fine crystalline, partly crinoidal, dolomitic limestone that ranges between 0 and 10 feet in thickness.

The youngest Mississippian unit in the Villa Grove Quadrangle is the Borden Siltstone, a deltaic deposit up to 600 feet thick (Swann et al. 1965, Lineback 1966) in the Illinois Basin. This unit is 0 to 350 feet thick in the Villa Grove Quadrangle. The Borden is dominantly a siltstone, but contains fine-grained sandstone lenses in the lower part (Lineback 1968). These lenses produce hydrocarbons in several oil fields in southern Illinois (Stevenson 1964). Other Mississippian units in the area include the Salem, St. Louis, and Ste. Genevieve Limestones, but they are absent in the Villa Grove Quadrangle. These limestones occur just to the west and south of the quadrangle and extend farther south and west into the Illinois Basin, where they form petroleum reservoirs. These units are an important source of construction aggregate and high-calcium limestone where they are near the surface along the edge of the basin in southern and western Illinois.

DEPOSITIONAL HISTORY

A relative drop in sea level at the end of the Silurian Period was followed by a period of non-deposition and erosion, resulting in a major unconformity between the Silurian rocks and the overlying Lower Devonian strata. Following a relative rise in sea level, normal marine conditions returned to the area, and a warm, shallow-water environment was established that promoted development of coral reefs (biohermal unit) in the Villa Grove Quadrangle and elsewhere in central Illinois. The reefs apparently developed adjacent to a relatively deeper-water setting that existed at the same time in the southern part of the basin.

Another regression-transgression cycle followed deposition of the biohermal unit. This cycle resulted in widespread deposition of sandstone in many areas in Illinois and across North America (Summerson and Swann 1970). In the Villa Grove Quadrangle, this regression-transgression cycle resulted in deposition of the Dutch Creek Sandstone. Deposition of the Dutch Creek was followed by a period of carbonate deposition that resulted in the formation of fossiliferous limestone of the Grand Tower Formation in southern Illinois (Devera 1986, Devera and Hasenmueller 1991). The Grand Tower environment was shallower and more restricted farther to the north in central Illinois and Indiana (Droste et al. 1975, Devera and Hasenmueller 1991). Close proximity of the Sangamon Arch (Nelson 1995) to the study area created shallow, hypersaline water conditions during deposition of the Grand Tower Formation. These rocks are lithologically closer to the fine, dolomitic fabrics of the Wapsipinicon Formation of northern Illinois, Missouri, and Iowa than they are to the normal marine limestone that was deposited in southern Illinois at this time. In the Villa Grove Quadrangle and adjacent areas, intertidal to supratidal conditions prevailed and resulted in deposition of a restricted marine facies characterized by stromatolitic laminations, mud cracks, and fenestral fabric. Windblown quartz sand grains were frequently transported in and incorporated within these dolomites. In such restricted, shallow-water settings, rapid evaporation of seawater formed magnesium-rich solutions that may have been responsible for formation of the microcrystalline dolomites of the Grand Tower Formation. The depositional settings of the Grand Tower in central Illinois resembled those currently present in the Persian Gulf or the Bahamas. Toward the end of Grand Tower deposition, volcanic eruptions in the Appalachian region of the eastern United States resulted in widespread deposition of volcanic ash that formed the Tioga(?) Bentonite Bed (Meents and Swann 1965).

After deposition of the Grand Tower Formation, normal marine conditions returned to central Illinois during deposition of the Lingle Formation. Warm, shallow seas prevailed at this time and resulted in development of coral reefs. A drop in sea level at the end of the Middle Devonian exposed the Lingle limestone to groundwater dissolution, which caused a major unconformity. The unconformity may have promoted development of a mixed lens of fresh and marine water (Badiozamani 1973) that may have been responsible for dolomitization of the upper part of the Lingle Formation.

Following deposition of the Lingle limestone, another major rise in sea level and subsequent transgression occurred, which caused development of anoxic conditions and resulted in widespread deposition of organic-rich black shale in North America. In the Illinois Basin and the Villa Grove Quadrangle, this rise in sea level is represented by the New Albany Shale, an important source rock for most of the petroleum found in many oil fields in the Illinois Basin (Cluff et al. 1981).

Following deposition of the New Albany, a major deltaic system advanced into the Illinois Basin from the northeast and deposited the Borden Siltstone during the Mississippian Period (Swann et al. 1965). This deltaic system was followed by deposition of a relatively thick limestone succession in the southern and western parts of Illinois, but very little carbonate deposition occurred in the Villa Grove Quadrangle during this period.

Uplift of the Tuscola Anticline began to accelerate during the Pennsylvanian Period. Erosion during and after deformation removed significant amounts of rock along the crest of the anticline. In some areas in the western part of the quadrangle, Pennsylvanian, Mississippian, Upper Devonian, and the upper part of the Middle Devonian were totally removed by erosion along the crest of the anticline. As a result, aggregate-quality, Silurian-Devonian limestone and dolomite are at the bedrock surface beneath a relatively thin Quaternary sediment cover along the crest of the anticline. The anticline was responsible not only for bringing aggregate resources near the surface but also for the trapping of hydrocarbons in nearby fields (e.g., Hays oil field, west of the Villa Grove Quadrangle).

REFERENCES

Badiozamani, K., 1973, The Dorag dolomitization model—Application to the Middle Ordovician of Wisconsin: Journal of Sedimentary Petrology, v. 43, p. 965–984.

Bell, A.H., 1943, Subsurface structure of the base of the Kinderhook-New Albany Shale in central and southern Illinois: Illinois State Geological Survey, Report of Investigations 92, 13 p.

Bristol, H.M., and R. Prescott, 1968, Geology and oil production in the Tuscola area, Illinois: Illinois State Geological Survey, Circular 424, 34 p.

Cluff, R.M., M.L. Reinbold, and J.A., Lineback, 1981, The New Albany Shale Group of Illinois: Illinois State Geological Survey, Circular 518, 83 p.

Collinson, C., G.W. James, D.H. Swann, L.E. Becker, M.P. Carlson, F.H. Dorheim, and J.W. Koenig, 1967, Devonian of the north-central region, United States, *in* D.H. Oswald, ed., International Symposium on the Devonian System, Calgary, 1967: Calgary, Alberta, Canada, Alberta Society of Petroleum Geologists, v. 1, p. 933–971. (Illinois State Geological Survey, Reprint 1968-G).

Devera, J.A., 1986, Micropaleontology, carbonate petrography, and environment of deposition of the Grand Tower Limestone in southwestern Illinois and southeastern Missouri: Carbondale, Illinois, Southern Illinois University, M.S. thesis, 322 p.

Devera, J.A., and G.H. Fraunfelter, 1988, Middle Devonian paleogeography and tectonic relationships east of the Ozark Dome, southeastern Missouri, southwestern Illinois and parts of southwestern Indiana and western Kentucky, *in* N.J. McMillan, A.F. Embry, and D.J. Glass, eds., Devonian of the world, v. II: Calgary, Alberta, Canada, Canadian Society of Petroleum Geologists, Memoir 14, p. 181–196.

Devera, J.A., and N.R. Hasenmueller, 1991, Kaskaskia Sequence—Middle and Upper Devonian Series through Mississippian Kinderhookian Series, *in* M.W. Leighton, D.R. Kolata, D.F. Oltz, and J.J. Eidel, eds., Interior Cratonic Basins: Tulsa, Oklahoma, American Association of Petroleum Geologists, Memoir 51, p. 113–123.

Droste, J.B., and R.H. Shaver, 1983, Atlas of Early and Middle Paleozoic paleogeography of the southern Great Lakes area: Bloomington, Indiana, Indiana Geological Survey, Special Report, 32 p.

Droste, J.B., R.H. Shaver, and J.D. Lazor, 1975, Middle Devonian paleogeography of the Wabash Platform, Indiana, Illinois, and Ohio: Geology, v. 3, p. 269–272.

Lineback, J.A., 1966, Deep-water sediments adjacent to the Borden Siltstone (Mississippian) delta in southern Illinois: Illinois State Geological Survey, Circular 401, 48 p.

Lineback, J.A., 1968, Turbidites and other sandstone bodies in the Borden Siltstone (Mississippian) in Illinois: Illinois State Geological Survey, Circular 425, 29 p.

Meents, W.F., and D.H. Swann, 1965, Grand Tower Limestone (Devonian) of southern Illinois: Illinois State Geological Survey, Circular 389, 34 p.

Nelson, W.J., 1995, Structural features in Illinois: Illinois State Geological Survey, Bulletin 100, 144 p.

Nelson, W.J., J.A. Devera, and J.M. Masters, 1995, Geology of the Jonesboro 15-minute Quadrangle, southwestern Illinois: Illinois State Geological Survey, Bulletin 100, 57 p.

North, W.G., 1969, The Middle Devonian strata of southern Illinois: Illinois State Geological Survey, Circular 441, 47 p.

Schwalb, H.R., 1955, Geneva (Middle Devonian) Dolomite in Illinois: Illinois State Geological Survey, Circular 204, 7 p.

Stevenson, D.L., 1964, Carper Sand oil production in St. James, Wilberton, and St. Paul Pools, Fayette County, Illinois: Illinois State Geological Survey, Circular 362, 12 p.

Summerson, C.H., and D.H. Swann, 1970, Patterns of Devonian Sand on the North American Craton and their interpretation: Boulder, Colorado, Geological Society of America, Bulletin, v. 81, p. 469–490.

Swann, D.H., J.A. Lineback, and E. Frund, 1965, The Borden Siltstone (Mississippian) delta in southern Illinois: Illinois State Geological Survey, Circular 386, 20 p.

Weibel, C.P., and Z. Lasemi, 2001, Geological map of the bedrock surface, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-BG, scale 1:24,000.

Chapter 9

Silurian-Devonian Rocks: Biostratigraphy

Rodney D. Norby and Curtis R. Klug[1]

Knowledge of the age and sequence of various geologic events (geologic history) is important for locating economically important resources such as coal, petroleum, and crushed stone aggregate. Previously identified bedrock aquifers can be traced by knowing the age of the bedrock containing the aquifer. The general age of the bedrock units underlying the Villa Grove Quadrangle ranges from approximately 530 million years (middle part of the Cambrian Period) to 300 million years (near the middle of the Pennsylvanian Period). The age of the lower 63 feet of exposed rock in the Tuscola Stone Company quarry is Late Silurian (Ludlow Epoch), and the remainder of the bedrock ranges in age from late Early Devonian to late Middle Devonian (fig. 9-1). These dates are based on conodont microfossils contained in the rocks. Older and younger bedrock units were not exposed, were never deposited, or were eroded away and could not be sampled to obtain detailed age information. Conodont biostratigraphy provided age information on two presently unnamed units: (1) a cherty dolomite (approximately 60 feet thick) in the Upper Silurian and (2) a biohermal dolomite (up to 45 feet thick) in the Lower Devonian (fig. 9-1).

DATING BEDROCK

The approximate ages for deposition of the various bedrock units (all within the Paleozoic Era) that occur at various depths in the Villa Grove Quadrangle are known through standard geological comparisons with similar rocks in other parts of the state or region. Although the general ages of the bedrock within the Villa Grove Quadrangle range between 300 (Pennsylvanian Period) and 530 million years old (Cambrian Period) (see Chapter 6), detailed age information is more useful and can be obtained either through radiometric dating, a technique not applicable to many rocks, or by the relative age dating technique termed *bio-stratigraphy*. Using this latter tool, a rock unit's age can be de-termined from the age of fossilized remains of organisms. The best fossils to utilize for biostratigraphy are those that existed as a species only for a relatively short period of time. Conodonts, a group of microfossils especially good for biostratigraphic analysis for much of the Paleozoic, were the major source of biostratigraphic information for the Villa Grove Quadrangle. The Tuscola Stone Company quarry east of Tuscola provided the only available exposure to determine the biostratigraphy of some of the rocks present in the quadrangle.

The lower half of the quarry, which includes rocks of Silurian and Devonian age, was sampled in detail for conodont microfossils by Norby. Rocks representing part of the upper half

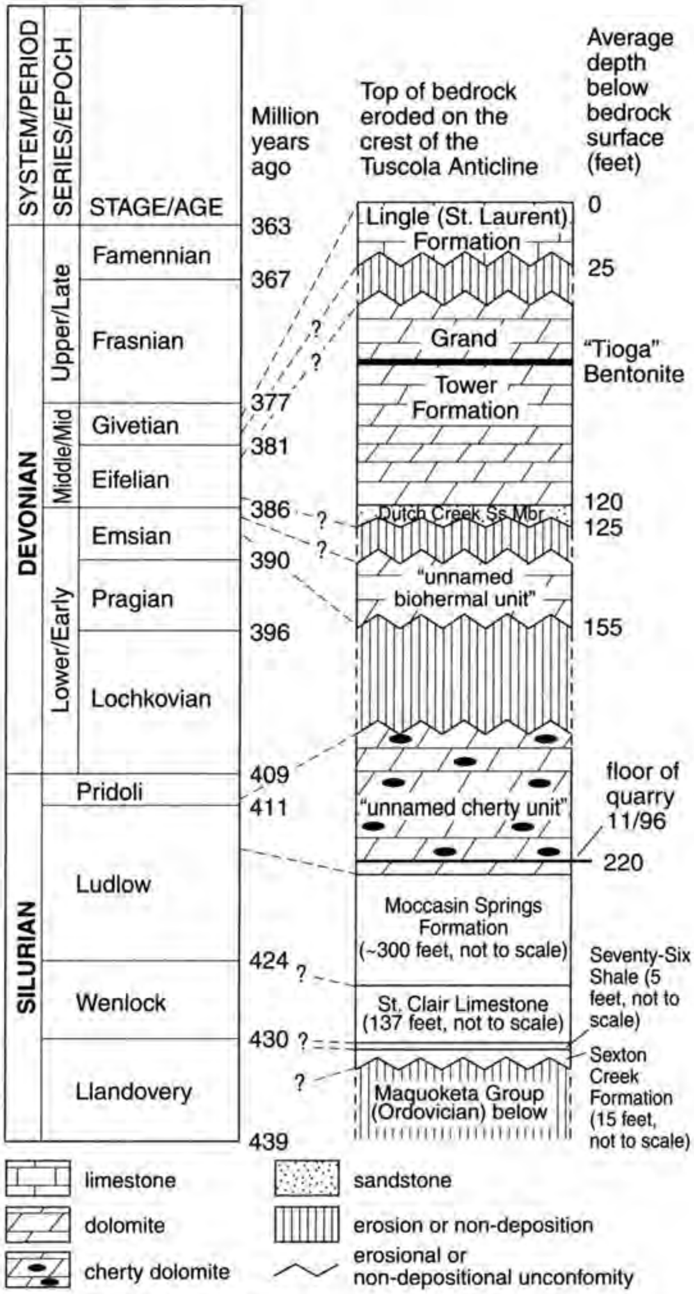


Figure 9-1 Age of rocks exposed in the Tuscola Stone Company quarry, Tuscola, Illinois, as of November 1996. Dashed lines between columns indicate the age of various rock units or time gaps; question marks along the dashed lines indicate that an age may be in doubt. Ages of designated formal age boundaries are from Harland et al.

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

[1]Present address: 12230 Shoreview Drive, Cape Coral, FL 33993.

of the quarry (Middle Devonian age) were examined and sampled by Klug from a rock core taken about 0.5 mile northwest of the quarry.

SILURIAN AGE ROCKS

The dolomite rock in the lower 63 feet of the quarry represents the upper part of the Silurian System (fig. 9-1) as determined from conodont microfossil samples. The most diagnostic species, *Ozarkodina* cf. *Ozarkodina snajdri,* is represented by a single specimen recovered from a sample approximately 35 feet below the top of the Silurian sequence. Most reports (Helfrich 1975, Denkler and Harris 1988) suggest that this species is restricted to the latter half of the Ludlow Epoch (fig. 9-1), although Kleffner (1995) indicates it also can occur in the early Pridoli Epoch, which occurred after the Ludlow. The range of this species also depends in part on the placement of the Ludlow-Pridoli boundary. If the identification of this species is correct, the age of the sample would be limited to the late Ludlow or possibly the early Pridoli. The sample occurs near the base of a depositional package that appears to extend to the top of the Silurian System. Therefore, the age of the upper 35 feet of the Silurian rocks is also probably late Ludlow or early Pridoli. The remaining conodonts that were recovered were common during the Ludlow and Pridoli (the latter two epochs of the Silurian), and some also have some earlier ranges in the Wenlock and Llandovery (the earliest two Silurian epochs). By lithology and general stratigraphic correlation (see Chapter 7), the Silurian rocks exposed in the Tuscola quarry appear to represent an unnamed cherty unit of Ludlow age that overlies the Moccasin Springs Formation (fig. 9-1). Since the last sampling in November 1996, the quarry has been deepened, and the top of the Moccasin Springs Formation is now exposed and will be sampled for future biostratigraphic studies.

DEVONIAN AGE ROCKS

An unnamed biohermal dolomite unit (see Chapter 8) that ranges from 5 to 45 feet thick directly overlies the unnamed cherty unit of the Silurian and is separated from it by a significant unconformity (fig. 9-1). This unconformity shows that rock representing over 20 million years of time either has been eroded away or was never deposited. Initial samples taken from the biohermal unit produced only a few conodont fragments in the lower samples, which is not unusual, because conodonts are typically rare to uncommon in a reef-type environment. Additional sampling of the inter-reef portion of the unit produced at least one or more conodont elements or fragments per sample, and most appeared to represent the same species. Although the specimens are typically broken, key features indicate the conodont *Icriodus huddlei* Klapper and Ziegler (Klapper and Ziegler 1967). The species is common in the Clear Creek Chert and Backbone Limestone (two recognized Lower Devonian rock formations) from southern Illinois (Collinson et al. 1967 [citing R.W. Orr, unpublished data], Willman et al. 1975). By compiling worldwide occurrences and ranges, Ziegler (1975) determined that this conodont has a short age range within the late Early Devonian (Emsian Stage); therefore, we believe that the biohermal unit is late Early Devonian in age.

Icriodus huddlei has also been reported from the Dutch Creek Sandstone Member (this unit directly overlies the Clear Creek) of the Grand Tower Limestone in southern Illinois (Collinson et al. 1967 [citing R.W. Orr, unpublished data]) and provided the previous rationale for placing the basal part of the Dutch Creek in the latest Emsian (Norby 1991). The specimens noted by Orr, however, may have been reworked from underlying beds of the Clear Creek Chert. Therefore, the Dutch Creek of southern Illinois is probably no older than earliest Middle Devonian, although additional confirming fossil evidence is absent. A single broken element of *Icriodus latericrescens robustus* (Orr 1971) was also found in a sample lower in the biohermal unit at the Tuscola quarry. Ranging in age from the middle to late Emsian through the Eifelian (Middle Devonian), this species has been found with *Icriodus huddlei* in the uppermost part of the Clear Creek Chert (Collinson et al. 1967 [citing R.W. Orr, unpublished data]). This species also occurs throughout most of the Grand Tower Limestone in southern Illinois (Collinson et al. 1967 [citing R.W. Orr, unpublished data]) and in the Jeffersonville Limestone and North Vernon Limestone of south-central Indiana (Klug 1983). This pattern suggests that the biohermal unit may be restricted to the latter part of the Emsian Stage.

The sandstone unit (fig. 9-1) that overlies the biohermal unit is 3 to 6 feet thick at the Tuscola quarry and probably equivalent to the Dutch Creek Sandstone Member of the Grand Tower Limestone of southern Illinois. Although conodonts are typically rare in a sandstone facies, this unit and the biohermal unit at the Tuscola quarry will be examined in more detail to verify the presence of a minor unconformity between it and the biohermal unit below. Therefore, the biohermal unit at the Tuscola quarry is definitely not related to the Silurian units below and may be unrelated in time to the overlying sandstone unit.

The sandstone is overlain by a unit 95 feet thick (fig. 9-1) that appears to be a dolomite facies of the Grand Tower Limestone of southern Illinois (Meents and Swann 1965, North 1969, Willman et al. 1975). The Grand Tower in a nearby core was sampled for conodonts and plant spores by Klug. The small samples from the core did not produce conodonts or diagnostic spores. Additional larger samples from the quarry walls will be collected to determine whether the age matches the Grand Tower of southern Illinois. The presence of a widespread bentonite, generally termed the “Tioga” Bentonite Bed, at approximately the same stratigraphic position in the formation at the Tuscola quarry and southern Illinois (Willman et al. 1975), suggests that they are equivalent units. There is some doubt whether this bentonite bed correlates with the type bed in Pennsylvania (Conkin and Conkin 1984). The characteristics of the rock samples from the Grand Tower in the quarry are typical of those deposited in a high-salinity marine environment that is hostile to many organisms; this marine environment may be the primary reason that no conodonts were recovered from this unit.

Conodont samples collected during the 1960s from the uppermost 25 feet of the quarry (fig. 9-1) indicate that these rocks are equivalent to probably the lower part of the Lingle (St. Laurent) Formation of southern Illinois (North 1969, Willman et al. 1975). These samples contained only a few species of conodonts, which are moderately short ranging, including *Polygnathus varcus* and *Icriodus latericrescens latericrescens*. These species indicate that the samples represent the *Polygnathus varcus* Biozone, which is restricted to the middle part of the Givetian Stage of the Middle Devonian Epoch.

One of the old samples, probably from the basal Lingle shale, is apparently from a shaley conglomeratic horizon, approximately 1 foot or less in thickness at the base of the Lingle Formation at this quarry. This sample contains a somewhat different fauna, including *Icriodus brevis* and *Icriodus* cf. *Icriodus arkonensis*. Conodonts from the basal Lingle shale are all restricted to the Givetian, and one, *Icriodus brevis* (Klapper 1975), is restricted to the *Polygnathus varcus* Biozone within the middle Givetian. Although the conodont fauna is somewhat different at the base of the Lingle, the fauna still indicates an age (Givetian) similar to that for the main part of the Lingle. These conodont ages indicate that a time gap occurred between the Lingle Formation and the underlying Grand Tower Formation.

REFERENCES

Collinson, C., G.W. James, D.H. Swann, L.E. Becker, M.P. Carlson, F.H. Dorheim, and J.W. Koenig, 1967, Devonian of the north-central region, United States, *in* D.H. Oswald, ed., International Symposium on the Devonian System, Calgary, 1967: Calgary, Alberta, Canada, Alberta Society of Petroleum Geologists, v. 1, p. 933–971. (Illinois State Geological Survey, Reprint 1968-G).

Conkin, J.E., and B.M. Conkin, 1984, Paleozoic metabentonites of North America, Part 1, Devonian metabentonites in the eastern United States and southern Ontario—Their identities, stratigraphic positions, and correlation: Louisville, Kentucky, University of Louisville Studies in Paleontology and Stratigraphy no. 16, 135 p.

Denkler, K.E., and A.G. Harris, 1988, *Homeognathus peniculus* (Conodonta)—A new earliest Pridolian index species and the Ludlovian-Pridolian boundary in the central Appalachian Basin: Reston, Virginia, U.S. Geological Survey, Bulletin 1837, Chapter C, C1–C11.

Harland, W.B., R.L. Armstrong, A.V. Cox, L.E. Craig, A.G. Smith, and D.G. Smith, 1990, A geologic time scale 1989: Cambridge, Massachusetts, Cambridge University Press, 263 p.

Helfrich, C.T., 1975, Silurian conodonts from Wills Mountain Anticline, Virginia, West Virginia, and Maryland: Boulder, Colorado, Geological Society of America, Special Paper 161, 82 p. plus 1 microfiche.

Klapper, G., 1975, *Icriodus brevis*, *in* W. Ziegler, ed., Catalogue of conodonts: Stuttgart, Germany, E. Schweizerbart'sche Verlagsbuchhandlung, v. 2, p. 89–90.

Klapper, G., and W. Ziegler, 1967, Evolutionary development of the *Icriodus latericrescens* group (Conodonta) in the Devonian of Europe and North America: Palaeontographica, v. 127, p. 68–83.

Kleffner, M.A., 1995, A conodont- and graptolite-based Silurian chronostratigraphy, *in* K.O. Mann and H.R. Lane, eds., Graphic correlation: SEPM (Society for Sedimentary Geology), Special Publication 53, p. 159–176.

Klug, C.R., 1983, Conodonts and biostratigraphy of the Muscatatuck Group (Middle Devonian), south-central Indiana and north-central Kentucky: Wisconsin Academy of Sciences, Arts and Letters, v. 7, pt. 1, p. 79–112.

Meents, W.F., and D.H. Swann, 1965, Grand Tower Limestone (Devonian) of southern Illinois: Illinois State Geological Survey, Circular 389, 34 p.

Norby, R.D., 1991, Biostratigraphic zones in the Illinois Basin, *in* M.W. Leighton, D.R. Kolata, D.F. Oltz, and J.J. Eidel, eds., Interior cratonic basins: Tulsa, Oklahoma, American Association of Petroleum Geologists, Memoir 51, p. 179–194.

North, W.G., 1969, Middle Devonian strata of southern Illinois: Illinois State Geological Survey, Circular 441, 45 p.

Orr, R.W., 1971, Conodonts from Middle Devonian strata of the Michigan Basin: Bloomington, Indiana, Indiana Geological Survey, Bulletin 45, 110 p.

Willman, H.B., E. Atherton, T.C. Buschbach, C. Collinson, J.C. Frye, M.E. Hopkins, J.A. Lineback, and J.A. Simon, 1975, Handbook of Illinois stratigraphy: Illinois State Geological Survey, Bulletin 95, 261 p.

Ziegler, W., 1975, *Icriodus huddlei*, *in* W. Ziegler, ed., Catalogue of conodonts: Stuttgart, Germany, E. Schweizerbart'sche Verlagsbuchhandlung, v. 2, p. 117–119.

Chapter 10

Pennsylvanian Rocks: Stratigraphy

C. Pius Weibel and Philip J. DeMaris
with contribution by Russel A. Peppers

Rocks of the Pennsylvanian System make up the bedrock surface beneath Quaternary strata over about 75% of the Villa Grove Quadrangle (fig. 10-1). These rocks consist of a relatively thin, basal, sandstone-dominated interval succeeded by a much thicker, shale-dominated interval (fig. 10-2). This latter interval is marked by distinctive, repetitive cycles of units of marine origin (black, fissile shale and gray limestone) deposited over units of terrestrial origin (e.g., coal). Pennsylvanian rocks attain a total thickness of about 390 feet near the center of the east edge of the Villa Grove Quadrangle in Sec. 36, T16N, R9E. The strata progressively thin toward the west, in the updip direction, and pinch out against the Tuscola Anticline, the axis of which approximately parallels the west edge of the quadrangle. The lithological descriptions below are based largely on study of core from a stratigraphic test well (VGDH-1, ISGS core 14944), drilled just south of Hugo (Sec. 13, T15N, R9E) (fig. 10-2 and Appendix 1). R.A. Peppers examined the palynomorph flora of the main coals in the core; these identifications (Appendix 1) were used to constrain our stratigraphic analysis. Additional data are from more than 120 other wells (mostly coal tests) from within and near the quadrangle.

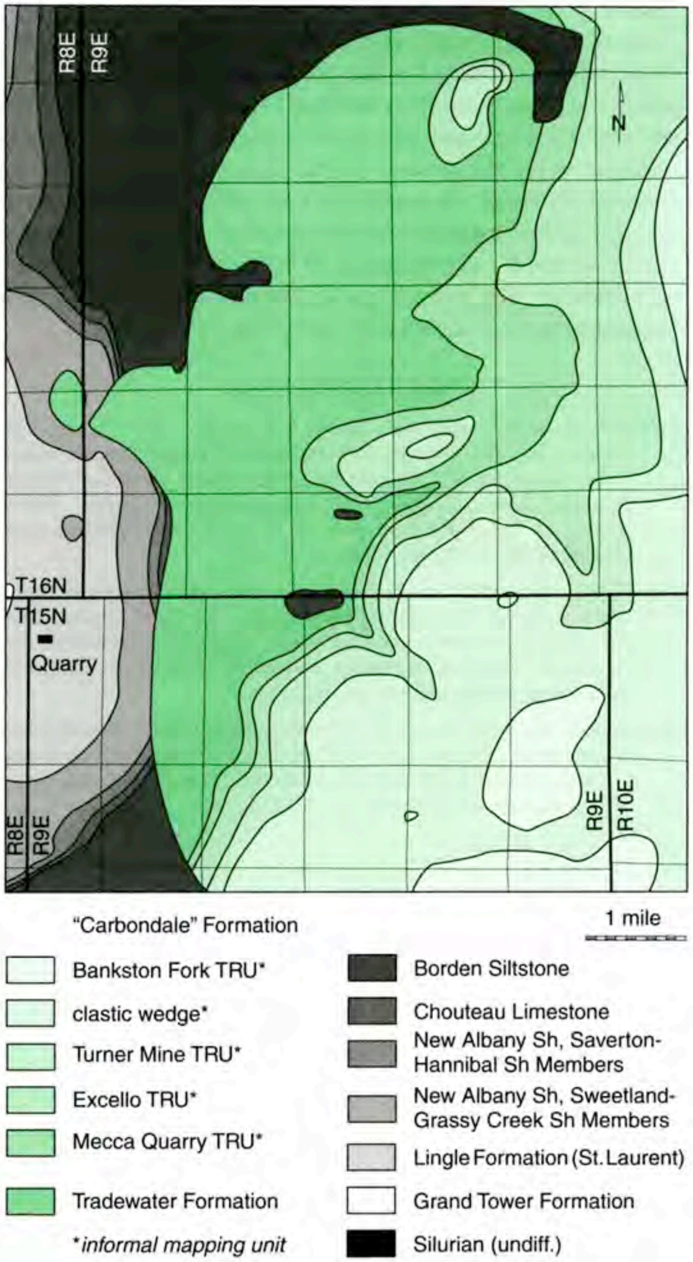


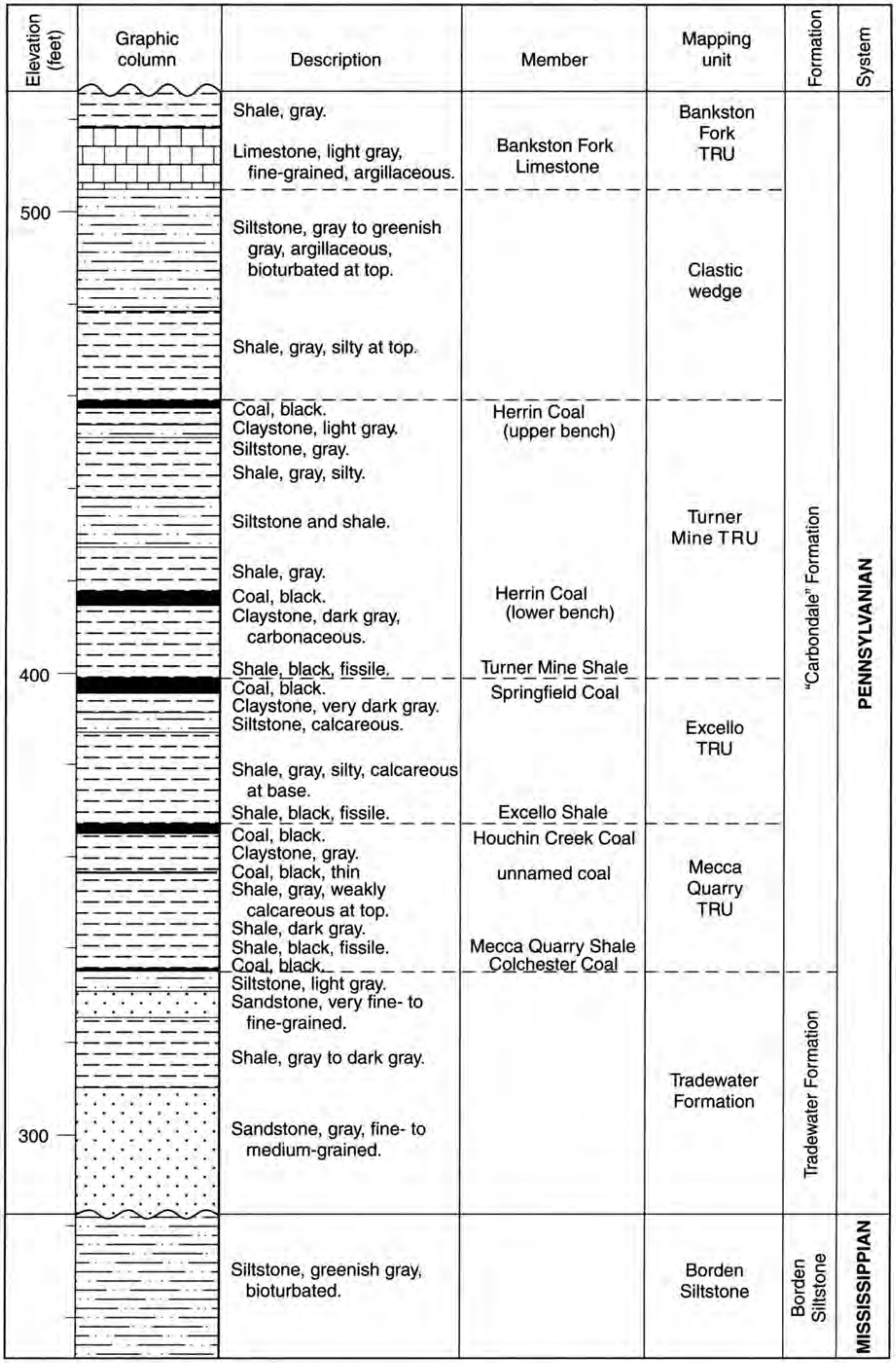
Figure 10-1 Generalized geologic map of the bedrock surface of the Villa Grove Quadrangle (modified from Weibel and Lasemi 2001). TRU, transgressive-regressive unit.

Figure 10-2 Stratigraphic column of the bedrock portion of the stratigraphic test well (VGDH-1; ISGS core 14944) Prosser No. VGDH-1, Sec. 13, T15N, R9E, Douglas County.

TRADEWATER FORMATION

The basal unit of the Pennsylvanian System, the Tradewater Formation, is dominated by a tan to light gray, fine- to medium-grained, quartz-rich sandstone (lithic arenite?). This unit is provisionally correlated with the Tradewater Formation of the southern Illinois Basin. Light gray to gray, coarse siltstone and medium to dark gray shale compose the remainder of this unit. The formation is non-calcareous; interbedded laminae composed of siltstone, mica, carbonaceous matter, or coal occur throughout the unit. In core VGDH-1, the formation is about 67% sandstone, 8% siltstone, and 25% shale and is 52.4 feet thick. Only a few other wells in the quadrangle penetrate this stratigraphic interval. Records from these other test holes are less clear than that from VGDH-1; they generally indicate similar lithologies, but some records indicate a higher percentage of the finer grained rocks. Three-dimensional computer modeling indicates that the unit is up to 250 feet thick near the center of the east edge (Sec. 36, T16N, R9E). Data used to derive the lower surface, the Mississippian-Pennsylvanian boundary, however, are sparse, and the model may not accurately represent the thickness and character of the rocks in this interval.

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.



Elevation (feet)
Graphic column
Description
Member
Mapping unit
Formation
System
500
400
300
Shale, gray.
Limestone, light gray, fine-grained, argillaceous.
Bankston Fork Limestone
Bankston Fork TRU
Siltstone, gray to greenish gray, argillaceous, bioturbated at top.
Shale, gray, silty at top.
Clastic wedge
Coal, black.
Claystone, light gray.
Siltstone, gray.
Shale, gray, silty.
Siltstone and shale.
Shale, gray.
Coal, black.
Claystone, dark gray, carbonaceous.
Shale, black, fissile.
Herrin Coal (upper bench)
Herrin Coal (lower bench)
Turner Mine Shale
Turner Mine TRU
Coal, black.
Claystone, very dark gray.
Siltstone, calcareous.
Shale, gray, silty, calcareous at base.
Shale, black, fissile.
Springfield Coal
Excello Shale
Excello TRU
Coal, black.
Claystone, gray.
Coal, black, thin
Shale, gray, weakly calcareous at top.
Shale, dark gray.
Shale, black, fissile.
Coal, black.
Houchin Creek Coal
unnamed coal
Mecca Quarry Shale
Colchester Coal
Mecca Quarry TRU
"Carbondale" Formation
Siltstone, light gray.
Sandstone, very fine- to fine-grained.
Shale, gray to dark gray.
Sandstone, gray, fine- to medium-grained.
Tradewater Formation
Tradewater Formation
PENNSYLVANIAN
Siltstone, greenish gray, bioturbated.
Borden Siltstone
Borden Siltstone
MISSISSIPPIAN

The Tradewater Formation, as all of the Pennsylvanian strata in this quadrangle, pinches out against the Tuscola Anticline. Because the formation was deposited on a significant erosional unconformity (the Mississippian-Pennsylvanian boundary), the thickness of the unit varies greatly. Three-dimensional modeling indicates that the unit is thickest (250 feet) in Sec. 36, T16N, R9E, east of Camargo. The strata were deposited in what was apparently part of a northeast-southwest–trending paleovalley that had been eroded into the underlying Borden Siltstone. This paleovalley is flanked by thinner deposits of the Tradewater. Near the center of the south edge of the quadrangle (Sec. 15, T15N, R9E), the unit thickens to 130 feet, but because of the small number of wells in this area, the thickness trends are uncertain.

The basal unit in VGDH-1 is correlated provisionally with the Tradewater Formation of the southern part of the Illinois Basin (Glenn 1912, Jacobson 1991) on the basis of the lithology of the sandstone and its stratigraphic position between the Mississippian Borden Siltstone below and the “Carbondale” Formation above. The top of the Tradewater Formation usually has been placed at the base of the Davis Coal (Williams et al. 1982), which is absent in this area. This basal unit may possibly be equivalent to strata below the Colchester Coal and above the Davis Coal. Resolution of this stratigraphic problem would entail a detailed regional study that is beyond the scope of this project. Because of the absence of the important key boundary unit, the Davis Coal, this basal unit is provisionally referred to as the Tradewater Formation.

It is also possible that sediments of the Caseyville Formation, the oldest Pennsylvanian formation in the basin, may have been deposited at the bottoms of paleovalleys that were eroded down into the Mississippian Borden Siltstone. Because VGDH-1 was drilled through the flank of a paleovalley and not its deepest part, the available data neither support nor refute this possibility. If present in the quadrangle, the Caseyville probably does not occur at the bedrock surface. In a regional study, Wanless (1955) indicated that the Caseyville is not present within this study area.

“CARBONDALE” FORMATION

The boundaries of the Carbondale Formation, originally named by Shaw and Savage (1912), have been modified several times (Hopkins and Simon 1975, Greb et al. 1992) and continue to drift (Nelson 1995). Despite this lack of stability in boundary definition, this unit is referred to here as the “Carbondale” Formation. The lower boundary of the “Carbondale,” the base of the Colchester Coal Member, is similar to that recognized by Kosanke et al. (1960) and commonly used for several decades. Kosanke et al. (1960) recognized the upper boundary as the top of the Danville Coal Member, which is not present in the quadrangle because of post-Pennsylvanian erosion. The Danville Coal occurs at or near the bedrock surface at the Murdock Mine, a few miles east of the quadrangle (C. Treworgy, personal communication). The “Carbondale” Formation attains a thickness of more than 190 feet in the southeast part of the quadrangle (Sec. 1 and Sec. 12, T15N, R9E). The lithology of the unit as represented in core VGDH-1 consists of 63.6% shale/claystone, 22.8% siltstone, 7.2% limestone, and 6.4% coal; as mentioned, it contains a distinctive repetition of marine units deposited over non-marine units.

Wanless and Weller (1932) introduced the term cyclothem for the cyclic units within the “Carbondale” and other formations. Recent studies (Weibel 1996, Miller and West 1998) indicated that mapping the base of the marine units (i.e., the transgressive surface) is more practical than mapping the basal discontinuity (lowstand unconformity) of cyclothems, as had been advocated by Wanless and Weller (1932). In the Villa Grove Quadrangle, the transgressive surface is a readily mappable horizon and is the boundary between the non-marine (coal) and marine (limestone, calcareous shale, and black, fissile shale) portions of each cycle. Marine units, particularly the black, fissile shales, are the most widespread lithologic units in the Pennsylvanian of the Illinois Basin (Wanless and Wright 1978). New, informal mapping units, consisting of a lower marine portion overlain by a non-marine portion and separated by a transgressive surface, were used to map the cyclic Pennsylvanian strata in this quadrangle. Such a mapping unit is referred to as a transgressive-regressive unit (terminology modified after Busch and Rollins 1984), or TRU. The name of each TRU is derived from the name of the basal marine bed.

Not all of the “Carbondale” strata fit within this transgressive-regressive stratigraphic framework. In the upper part of the formation, near the south edge of the quadrangle, thick deposits of deltaic sediments (shale and siltstone) were deposited during and after the deposition of the Herrin Coal (Treworgy and Treworgy 1983). These deltaic sediments lack the basal marine transgressive strata and thus do not readily fit into the transgression-regression framework. These strata are mapped as separate units and are informally referred to as clastic wedges.

“Carbondale” Mapping Units

The “Carbondale” Formation in this quadrangle is thus divided into five major lithologic mapping units that are composed of either (1) relatively thin, widespread strata, which represent successive marine and non-marine depositional environments, or (2) relatively thick wedges of clastic dominated strata, which represent prograding deltaic environments. In general, each TRU consists of a basal marine unit (limestone, black shale, or calcareous shale), a gray shale, an underclay, and a coal at the top. Each TRU may contain some or all of these units.

1. ***Mecca Quarry TRU*** The lowest “Carbondale” mapping unit is the Mecca Quarry TRU (figs. 10-1 and 10-2), which consists of strata from the base of the Colchester Coal Member to the top of the Houchin Creek Coal Member. This TRU is an exception to the TRU definition just provided because it includes a basal, non-marine coal stratum, the Colchester Coal Member. This coal was included as part of the Mecca Quarry TRU so that the basal boundary of the “Carbondale” Formation would also be a mapping unit boundary. The Colchester Coal is the uppermost portion of an unmappable TRU in which the lower portion is

either not present or not identifiable in the quadrangle. The Mecca Quarry Shale Member, a black fissile shale, is the basal marine stratum just above the Colchester Coal, and the top stratum is the underclay claystone of the Houchin Creek Coal. A TRU that is too thin to map separately (~5 feet thick) occurs just below the Houchin Creek Coal Member. The lower boundary of this TRU is indicated by a very thin, unnamed black marine shale that overlies a very thin (0.05 feet) unnamed coal. This coal is possibly equivalent to the Kerton Creek Coal (Ekblaw 1931, Wanless 1957) or to the Survant Coal (Kosanke et al. 1960, Jacobson et al. 1985). The unnamed coal is succeeded by a calcareous claystone that grades up into the underclay claystone of the Houchin Creek. Because this thin TRU is only recognized in a few wells in the quadrangle, it is grouped with the Mecca Quarry TRU. The complete Mecca Quarry TRU is generally about 30 to 35 feet thick.

2. ***Excello TRU*** The second mapping unit is the Excello TRU, which consists of strata from the base of the Excello Shale Member (equivalent to the top of the Houchin Creek Coal) to the top of the Springfield Coal Member. The widespread Excello Shale, a black fissile shale, and the overlying calcareous, fossiliferous gray shale form the basal marine strata above the Houchin Creek. An underclay claystone and the Springfield Coal are the non-marine rocks that mark the top of the TRU. The thickness of this mapping unit is generally between 25 and 35 feet.

3. ***Turner Mine TRU*** The third mapping unit is the Turner Mine TRU, which generally consists of strata from the base of the Turner Mine Shale Member (equivalent to the top of Springfield Coal) to the top of the Herrin Coal Member. In the VGDH-1 core, however, the basal marine strata are a thin marine facies of the Dykersburg(?) Shale (fig. 10-3; not shown on fig. 10-2), which, in turn, is overlain by the more widespread Turner Mine Shale (figs. 10-2 and 10-3).

   A similar marine facies of the Dykersburg Shale was first identified in Gallatin County, Illinois, in the Eagle No. 2 mine (DeMaris, unpublished ISGS mine notes, November 8, 1990), where it occurred in discrete lenses up to 1.5 feet thick. The type Dykersburg Shale is a non-marine shale that overlies the Springfield Coal in southeastern Illinois (Hopkins 1968). The Dykersburg marine facies was identified in this study on the basis of *Dunbarella* fossils and geochemistry similar to that of the mine sample. This marine facies may be an analog of the marine shelf facies of the Energy Shale of southwestern Illinois (DeMaris and Nelson 1990), where it occurs as roof strata of the Herrin Coal.

   A shale above the basal marine strata grades up into an underclay claystone, which is succeeded by the Herrin Coal. Near the southern edge of the quadrangle, the Herrin Coal is split into upper and lower benches by a thick wedge of clastic sediments. In this area, the sediments between the lower and upper benches of the Herrin consist of shale and siltstone capped by a thin underclay claystone. This wedge of sediments represents the deposition of terrestrial deltaic sediments that interrupted the deposition of the Herrin Coal (Treworgy and Treworgy 1983). The split (deltaic wedge) is included as part of the Turner Mine TRU. The thickness of this mapping unit ranges from about 20 to 55 feet; the unit is thicker where the split is present and thinner where it is absent. For additional details on the geology of the Herrin Coal and the split, see Treworgy (1999).

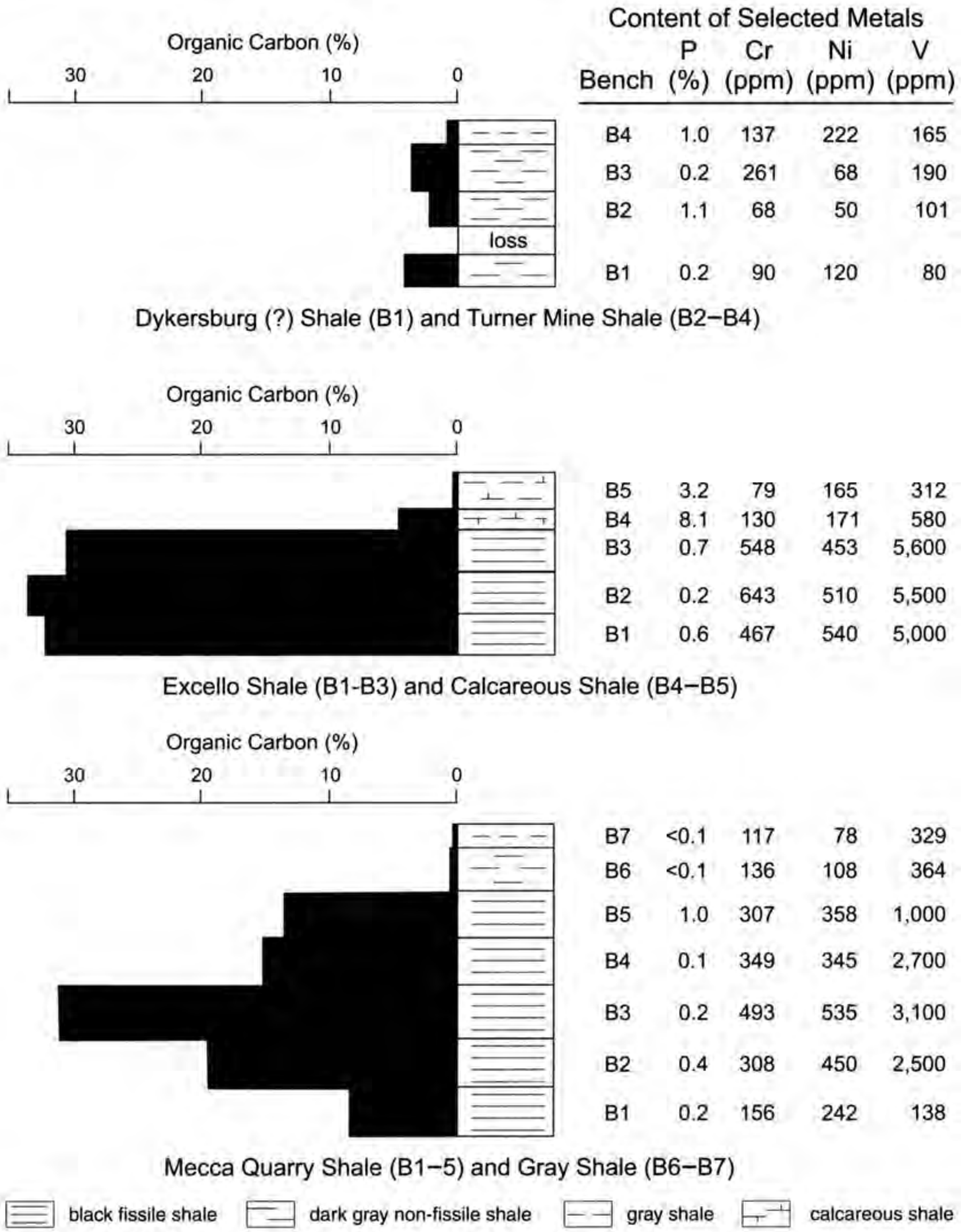
4. ***Clastic wedge*** The fourth mapping unit is the clastic wedge, which consists of strata from the top of either the Herrin Coal or, at the southern edge of the quadrangle, the upper Herrin Coal, to the base of the Bankston Fork Limestone Member. It consists of a wedge-shaped succession of shale and siltstone that Treworgy and Treworgy (1983) interpreted to have in-filled at the time of deposition a topographically low area. This mapping unit lacks basal marine transgressive strata and thus is not referred to as a TRU. The thickness of this unit varies from about 45 to 80 feet. Much of this variance is also due to the presence of the sediment wedge in the underlying Herrin Coal.

5. ***Bankston Fork TRU*** The uppermost and fifth mapping unit of the “Carbondale” Formation is the Bankston Fork TRU, which in this quadrangle consists of strata from the base of the Bankston Fork Limestone to the top of Pennsylvanian bedrock. The limestone, which is the basal marine unit, attains a thickness of 13.6 feet and is overlain unconformably by a gray shale/claystone. The unconformity (see description, Appendix 1) may represent an exposure of the limestone during the early regression, prior to being covered by the prograding overlying shale. The absence of the upper part of this cyclic unit in the quadrangle is due to post-Pennsylvanian erosion. This mapping unit attains a maximum thickness of about 30 feet in the southeast part of the quadrangle (Sec. 12 and Sec. 14, T15N, R16E).

CHEMO-STRATIGRAPHY OF CARBONACEOUS SHALES

Geochemical analyses of the black, fissile, carbonaceous shales that occur in core VGDH-1 were undertaken because these shales are important Pennsylvanian stratigraphic markers within this quadrangle and throughout the midcontinent (Coveney et al. 1987, Hatch and Leventhal 1997). The units are increasingly being utilized for local and regional correlations (Weibel 1991), and they are often readily recorded on the downhole gamma-ray geophysical logs.

These organic-rich units are part of the marine successions immediately above each of three coals. These successions are (1) the Colchester Coal, succeeded by the black Mecca Quarry Shale; (2) the Houchin Creek Coal, succeeded by the black Excello Shale; and (3) the Springfield Coal, succeeded by the dark gray Dykersburg Shale and the black Turner Mine Shale (fig. 10-3). Marine strata succeeding the Herrin Coal are insignificant in this quadrangle, probably because deposition of the wedge of the terrestrial deltaic sediments restricted marine deposition.



Content of Selected Metals

Dykersburg (?) Shale (B1) and Turner Mine Shale (B2–B4)

Bench	P (%)	Cr (ppm)	Ni (ppm)	V (ppm)
B4	1.0	137	222	165
B3	0.2	261	68	190
B2	1.1	68	50	101
B1	0.2	90	120	80

Excello Shale (B1-B3) and Calcareous Shale (B4–B5)

Bench	P (%)	Cr (ppm)	Ni (ppm)	V (ppm)
B5	3.2	79	165	312
B4	8.1	130	171	580
B3	0.7	548	453	5,600
B2	0.2	643	510	5,500
B1	0.6	467	540	5,000

Mecca Quarry Shale (B1–5) and Gray Shale (B6–B7)

Bench	P (%)	Cr (ppm)	Ni (ppm)	V (ppm)
B7	<0.1	117	78	329
B6	<0.1	136	108	364
B5	1.0	307	358	1,000
B4	0.1	349	345	2,700
B3	0.2	493	535	3,100
B2	0.4	308	450	2,500
B1	0.2	156	242	138

Figure 10-3 Organic carbon and selected metal contents of marine units succeeding coal beds in the Villa Grove Quadrangle.

These three marine shales and, to a lesser extent, the marine facies of the Dykersburg Shale have elevated concentrations of organic carbon, barium, cadmium, chromium, copper, molybdenum, nickel, phosporus, strontium, vanadium, zinc, and pyrite. The thorium and uranium concentrations are also elevated and cause a strong gamma response on geophysical logs. Geochemical analyses of benched samples of these shales indicate depositional environments ranging from poorly oxygenated to totally anoxic (Hatch and Leventhal 1997). These anoxic environments allowed the accumulation of very carbonaceous sediments; some benches of the Mecca Quarry and Excello Shales (fig. 10-3) have as much as 33% organic carbon. The lower organic carbon content of the Turner Mine Shale suggests that the depositional environment of this unit was predominantly dysoxic.

REFERENCES

Busch, R.M., and H.B. Rollins, 1984, Correlation of carboniferous strata using a hierarchy of transgressive-regressive units: Geology, v. 12, p. 471–474.

Coveney, R.M., J.S. Leventhal, M.D. Glascock, and J.R. Hatch, 1987, Origins of metals and organic matter in the Mecca Quarry Shale Member and stratigraphically equivalent beds across the Midwest: Economic Geology, v. 82, p. 915–933.

DeMaris, P.J., and W.J. Nelson, 1990, Geology of the Herrin Coal at Crown II Mine, Virden, Macoupin County, Illinois, *in* W.R. Hammer and D.F. Hess, eds., Geology field guidebook—Current perspectives on Illinois Basin and Mississippi Arch geology: 24th Annual Meeting of the North-Central Section, Geological Society of America, Western Illinois University, Macomb, Illinois. p. D1–D16. (ISGS Reprint 1990-D.)

Ekblaw, S.E., 1931, Channel deposits of the Pleasantview Sandstone in western Illinois: Transactions of the Illinois State Academy of Science, v. 23, p. 391–399.

Glenn, L.C., 1912, The geology of Webster County, *in* C.J. Norwood, ed., Report on the progress of the Survey for the years 1910 and 1911: Lexington, Kentucky, Kentucky Geological Survey, p. 25–35.

Greb, S.F., D.A. Williams, and A.D. Williamson, 1992, Geology and stratigraphy of the Western Kentucky Coal Field: Lexington, Kentucky, Kentucky Geological Survey, Bulletin 2, Series XI, 77 p.

Hatch, J.R., and J.S. Leventhal, 1997, Early diagenetic partial oxidation of organic matter and sulfides in the Middle Pennsylvanian (Desmoinesian) Excello Shale Member of the Fort Scott Limestone and equivalents, northern midcontinent region, U.S.A.: Chemical Geology, v. 134, p. 215–235.

Hopkins, M.E, 1968, Harrisburg (No. 5) Coal reserves of southeastern Illinois: Illinois State Geological Survey, Circular 431, 49 p.

Hopkins, M.E, and J.A. Simon, 1975, Pennsylvanian System, *in* H.B. Willman, E. Atherton, T.C. Buschbach, C. Collinson, J.C. Frye, M.E. Hopkins, J.A. Lineback, and J.A. Simon, Handbook of Illinois stratigraphy: Illinois State Geological Survey, Bulletin 95, p. 163–201.

Jacobson, R.J., 1991, Geologic map of the Goreville Quadrangle, Johnson and Williamson Counties, Illinois: Illinois State Geological Survey, IGQ- 7, scale 1:24,000.

Jacobson, R.J., C.B. Trask, C.H. Ault, D.P. Carr, H.H. Gray, W.A. Hasenmueller, D.A. Williams, and A.D. Williamson, 1985, Unifiying nomenclature in the Pennsylvanian System of the Illinois Basin: Transactions of the Illinois State Academy of Science, v. 78, p. 1–11.

Kosanke, R.M., J.A. Simon, H.R. Wanless, and H.B. Willman, 1960, Classification of the Pennsylvanian strata of Illinois: Illinois State Geological Survey, Report of Investigations 214, 84 p.

Miller, K.B., and R.R. West, 1998, Identification of sequence boundaries within cyclic strata of the Lower Permian (Wolfcampian) of Kansas—Problems and alternatives: Journal of Geology, v. 106, p. 119–132.

Nelson, W.J., 1995, Bedrock geology of the Paducah 1 × 2 Quadrangle: Illinois, Kentucky, and Missouri: Illinois State Geological Survey, Bulletin 102, 40 p.

Shaw, E.W., and T.E. Savage, 1912, Description of the Murphysboro-Herrin Quadrangles: U.S. Geological Survey, Atlas Folio 185, 15 p.

Treworgy, C.G., 1999, Coal resources map and availability for mining, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-CR, scale 1:24,000.

Treworgy, J.D., and C.G. Treworgy, 1983, A new feature in the Pennsylvanian of the Illinois Basin—Clastic in-filling of a lacustrine basin (abstract): Abstracts with Programs, Geological Society of America, p. 708.

Wanless, H.R., 1955, Pennsylvanian rock of Eastern Interior Basin: Tulsa, Oklahoma, American Association of Petroleum Geologists Bulletin, v. 39, no. 9, 1753–1820.

Wanless, H.R., 1957, Geology and mineral resources of the Beardstown, Glasford, Havana, and Vermont Quadrangles: Illinois State Geological Survey, Bulletin 82, 233 p.

Wanless, H.R., and J.M. Weller, 1932, Correlation and extent of Pennsylvanian cyclothems: Boulder, Colorado, Geological Society of America Bulletin, v. 43, p. 1003–1016.

Wanless, H.R., and C.R. Wright, 1978, Paleoenvironmental maps of Pennsylvanian rocks of the Illinois Basin and northern midcontinent region: Boulder, Colorado, Geological Society of America, Map and Chart Series MC-23.

Weibel, C.P., 1991, Sequence stratigraphy in mixed clastic-carbonate strata, Upper Pennsylvanian, East-Central Illinois: Great Lakes Section, Society of Economic Paleontologists and Mineralogists, 21st Annual Field Conference, 80 p.

Weibel, C.P., 1996, Applications of sequence stratigraphy to Pennsylvanian strata in the Illinois Basin, *in* B.J. Witzke, G.A. Ludvigson, and J. Day, eds., Paleozoic sequence stratigraphy—Views from the North American Craton: Boulder, Colorado, Geological Society of America, Special Paper 306, p. 331–339.

Weibel, C.P., and Z. Lasemi, 2001, Geological map of the bedrock surface, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-BG, scale 1:24,000.

Williams, D.A., A.D. Williamson, and J.G. Beard, 1982, Stratigraphic framework of coal-bearing rocks in the Western Kentucky Coal Field: Lexington, Kentucky, Kentucky Geological Survey, Series XI, Information Circular 8, 201 p.

Chapter 11

QUATERNARY GEOLOGY

Ardith K. Hansel, Richard C. Berg, and Curtis C. Abert

Overlying the bedrock of the Villa Grove Quadrangle are unlithified materials deposited during the Quaternary Period (past 1.6 million years). Most of these deposits are related to the glaciers that covered the area during three glacial episodes, but they also include materials that were deposited during interglacial episodes, including the current postglacial episode. The Quaternary deposits range from 35 feet to over 260 feet thick in the quadrangle. The variation in thickness of these deposits is primarily due to variation in bedrock topography (fig. 11-1) and, to a lesser extent, surface topography.

The deposits related to glacial episodes consist of (1) diamictons (non-sorted to poorly sorted mixtures of gravel, sand, silt, and clay) deposited predominantly by glacial ice and interpreted to be till; (2) stratified sand and gravel materials deposited by glacial meltwaters and interpreted to be outwash and deltaic sand; (3) laminated silts and clays deposited in glacial lakes; and (4) massive silts (loess) deposited by glacial winds. Non-glacial sediments consist of sorted sediments deposited by water in rivers, streams, lakes, and ponds and non-sorted to poorly sorted sediments deposited by gravity along slopes. Where Quaternary materials were or are at the land surface, they are leached and weathered and record soil development during non-glacial intervals. Figure 11-2 shows the distribution of Quaternary materials at the land surface.

The Quaternary materials of the glacial and non-glacial episodes are classified into lithostratigraphic units on the basis of their lithology and stratigraphic position. Figure 11-3 shows relationships among the lithostratigraphic units and the positions of buried soils.

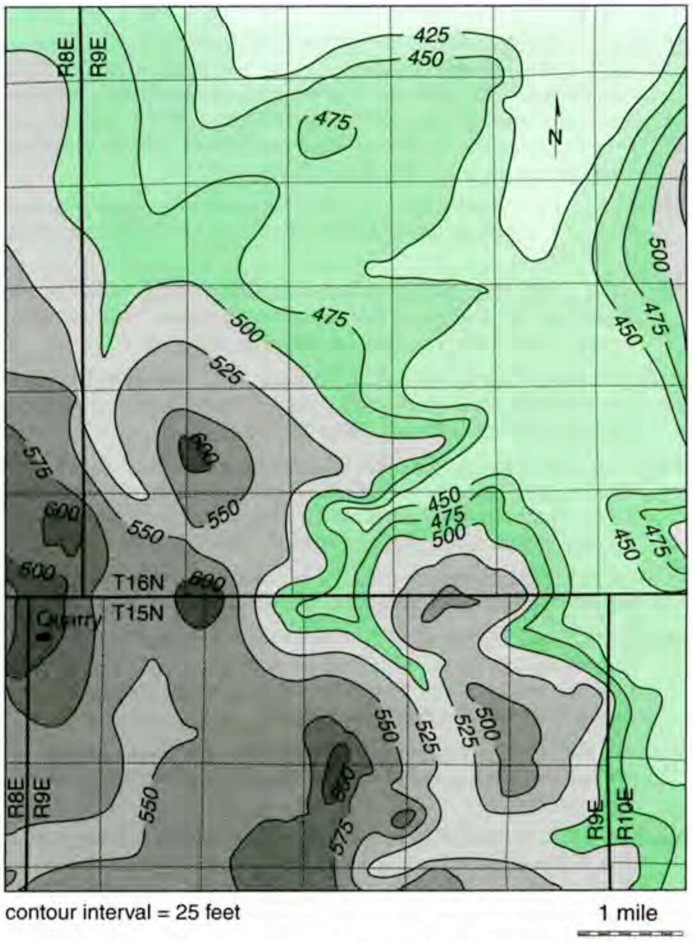


Figure 11-1 Bedrock surface topography of the Villa Grove Quadrangle (modified fromWeibel 1999).

METHODOLOGY

The near-surface and buried Quaternary deposits of the Villa Grove Quadrangle were mapped using the following data and approach:

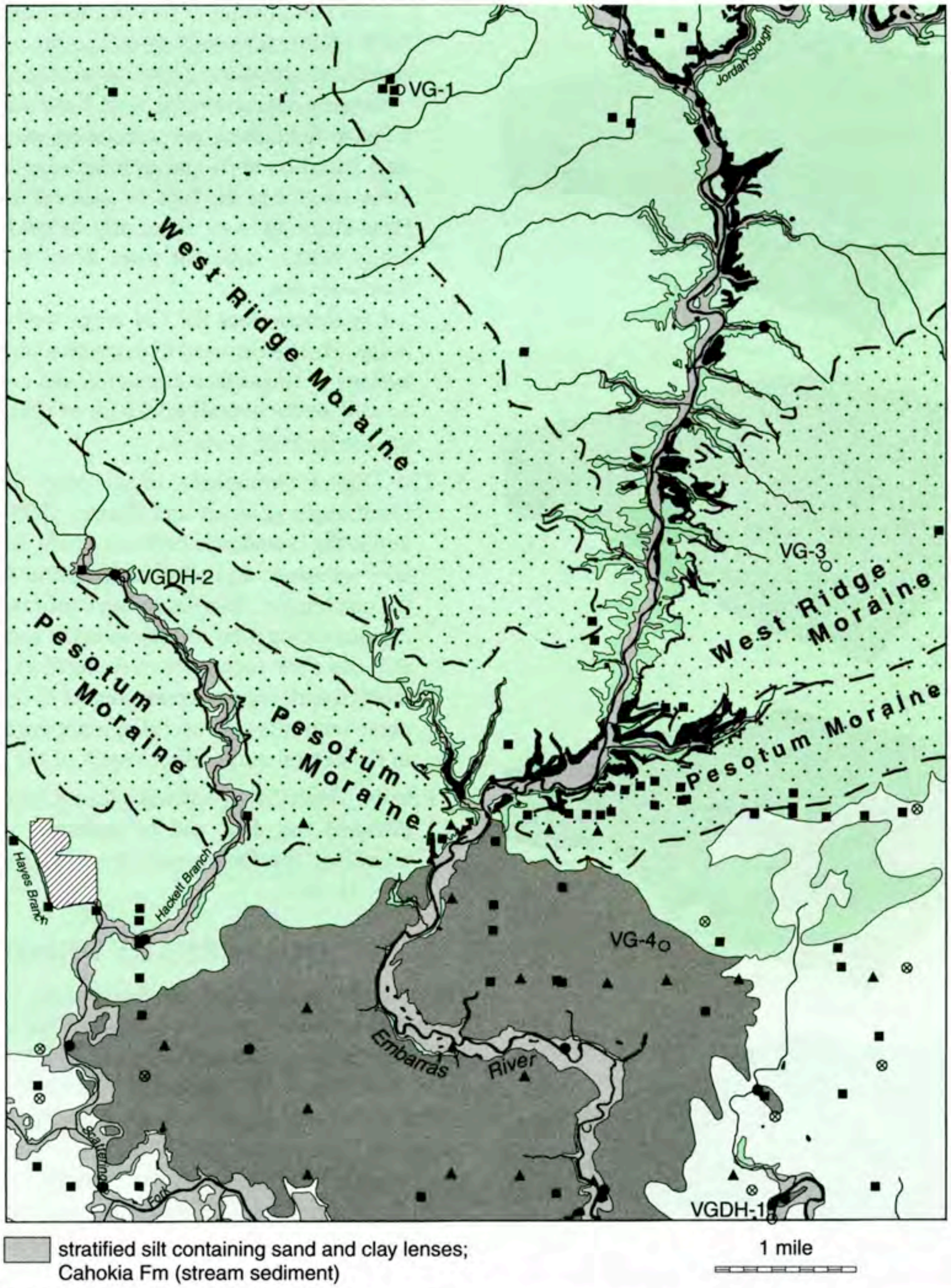
1. A preliminary map showing geologic materials of the uppermost 5 feet was produced by using the U.S. Department of Agriculture, Soil Conservation Service (now the Natural Resources Conservation Service) soil survey maps for Douglas County (Hallbick and Fehrenbacher 1971). Soil series were differentiated according to their composition and landscape position and then classified into groups according to geologic parent material. This exercise was very useful for defining the boundary of river sediment along river and stream courses and the location of diamicton on uplands. However, soil information was less useful for defining geologic material boundaries in the relatively flat, lowland area in the southern portion of the quadrangle where silty sediments deposited in a glacial lake are similar in terms of materials to loess and silty till.

2. To confirm the near-surface geology and define subsurface units, logs and sample descriptions were evaluated (see fig. 11-2 for the location of the data points).

   Drilling logs for 12 engineering (bridge) borings from state, county, and township highway departments were used to determine the thickness of river and stream sediment.

   Logs of hand-augered test holes from 20 locations from Fraser and Steinmetz (1971) and sample descriptions of nine new shallow test borings (<15 feet) drilled with the Illinois State Geological Survey (ISGS) Giddings drill rig were used to determine the thicknesses of the sandy deltaic deposits and finer grained lake sediments.

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.



stratified silt containing sand and clay lenses; Cahokia Fm (stream sediment)

loosely consolidated loam or silt loam diamicton over compact silt loam diamicton; Peyton Fm over Batestown Mbr (slope deposits over till)

leached silt (1–4 feet) over up to 11 feet of stratified sand; Peoria Silt over Henry Fm (loess over deltaic sediment)

leached silt (up to 4 feet) over up to 20 feet of laminated silt and silty clay; Peoria Silt over Equality Fm (loess over lake sediment)

leached silt (1–4 feet) over silt loam diamicton; Peoria Silt over Batestown Mbr (loess over till)

leached silt (<1 feet) over silt loam diamicton; thin Peoria Silt over Batestown Mbr (thin loess over till)

surface water

surface mine

○ ISGS test boring

⊗ ISGS shallow test boring (<15 feet deep)

■ shallow boring to verify upper 5 feet

▲ shallow boring (from Fraser and Steinmetz)

● engineering boring

Figure 11-2 Generalized surficial geology of the Villa Grove Quadrangle. Shown are locations of borings/logs (except for water wells) that were used to map Quaternary materials (modified from Hansel et al. 1999).

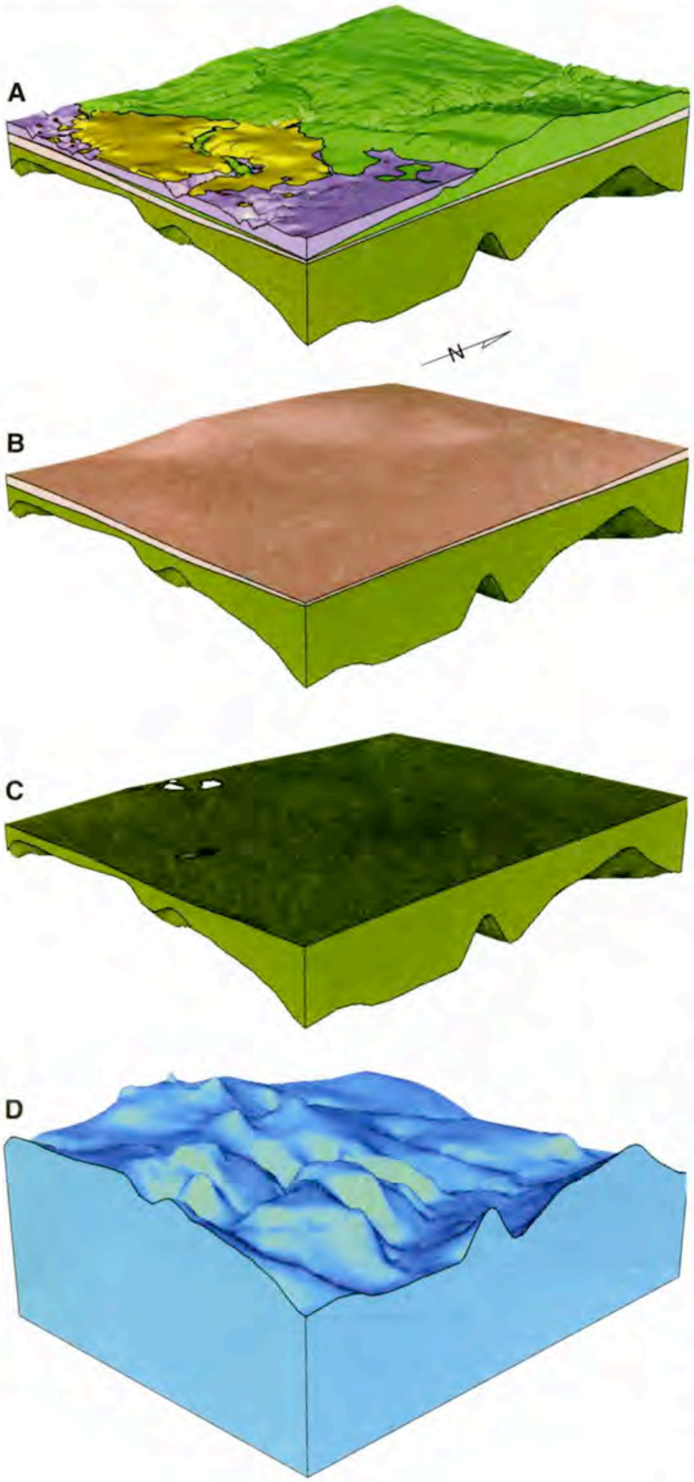


Figure 11-3 Generalized three-dimensional model of the Quaternary deposits and bedrock surface of the Villa Grove Quadrangle as viewed from the southeast. (A) All Quaternary deposits. (B) Deposits of the Hudson and Wisconsin Episodes are stripped away so that the topography on top of the Illinois Episode Glasford Formation is visible. (C) Deposits of the Hudson, Wisconsin, and Illinois Episodes are stripped away so that the topography on top of the pre-Illinois episode Banner Formation is visible. (D) Quaternary deposits are stripped away so that the bedrock topography is visible. Vertical exaggeration: 40×.

Logs and samples of five new test borings drilled with the ISGS Mobile B30s drill rig and a contract drill rig were evaluated to establish the deeper subsurface geology (>30 feet).

Seventy-seven borings were hand-augered to a depth of 5 feet to field check the preliminary map of geologic materials based on soils and to determine the thickness of the loess cover and the type of material underlying the loess. Hand-augering was especially helpful in differentiating sandy deltaic sediment from diamicton and fine-grained lake sediment.

Log descriptions for 124 water-well borings (not shown in fig. 11-2) were used to determine thicknesses and distributions of subsurface diamicton and sand and gravel units as well as the overall thickness of glacial deposits overlying the bedrock surface.

3. The Digital Orthophoto Image Map for the Villa Grove Quadrangle (Luman and Hansel 1999) was used to help define the boundaries between sandy deltaic sediment, silty lake sediment, and silty diamicton in the southern part of the quadrangle. Hand-augering confirmed that light-colored regions on the map corresponded to sandy deltaic deposits, uniform dark regions corresponded to lake sediment, and mottled dark regions corresponded to diamicton. The orthophoto map was also useful in mapping moraine boundaries in the central and northern parts of the quadrangle.
4. Finally, EarthVision software (see Chapter 3) was used to interpret the data and to generate a three-dimensional model of the Quaternary deposits and bedrock surface (fig. 11-3).

QUATERNARY DEPOSITS

Glaciers advanced and retreated across the Villa Grove area and deposited sediment during at least three episodes (from oldest to youngest, the pre-Illinois, Illinois, and Wisconsin glacial episodes; fig. 11-4). Figure 11-5 shows the 35 to 40 feet of Quaternary sediment that overlies the bedrock at the Tuscola Stone Company quarry and records the glacial history of the area. In this exposure, evidence for three glacial episodes and four non-glacial episodes is preserved. The Quaternary sediment is predominantly till layers that were deposited by ice during glacial episodes. Soil horizons formed in these layers during interglacial (non-glacial) episodes, when the climate was similar to that of today. During the non-glacial episodes, weathering resulted in soil formation and oxidation in the upper part of the till unit that was at the surface at the time. The buried soils are the redder colored zones in the deposits above the bedrock in figure 11-5. Whereas the postglacial soil has formed since glaciers melted from the area about 18,000 years ago, an interglacial soil, the Sangamon Geosol, formed between the Wisconsin and Illinois Episodes (about 75,000 to 125,000 years ago), and an even older soil—the Yarmouth Geosol—formed between the Illinois and pre-Illinois episodes (from about 180,000 to more than 500,000 years ago). Prior to glaciation, the bedrock was exposed to weathering after its deposition in the Pennsylvanian Period. A preglacial soil developed in bedrock can be seen in the lower right part of figure 11-5.

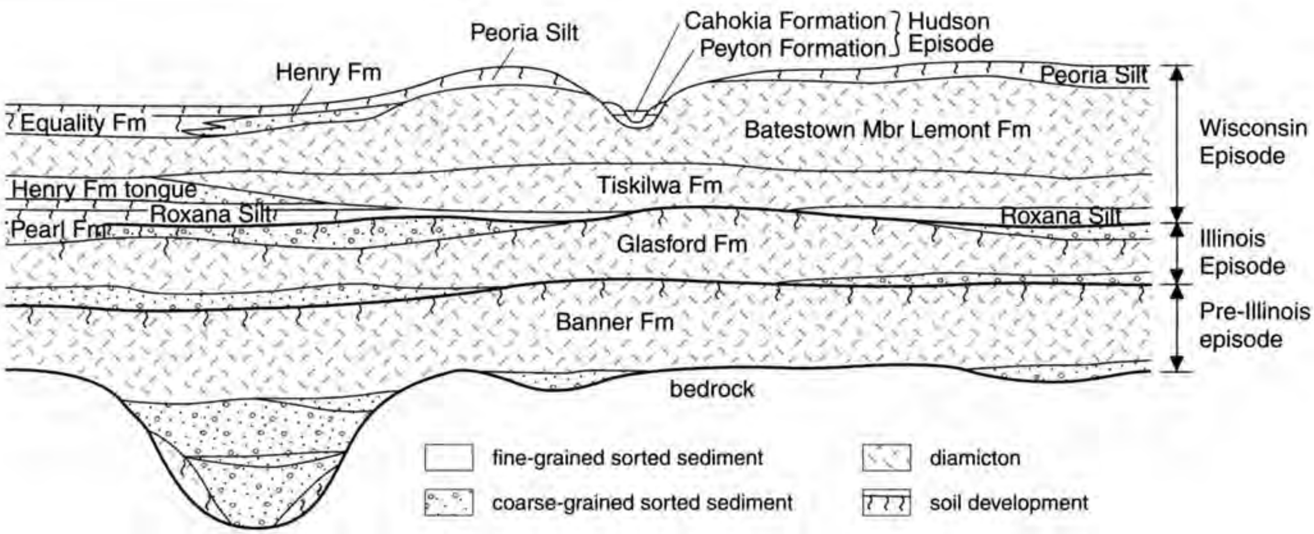


Figure 11-4 Relationships among Quaternary lithostratigraphic units and buried soils of the Villa Grove Quadrangle and their association with glacial (Wisconsin, Illinois, and pre-Illinois) and postglacial (Hudson) episodes. Sorted sediments of the Wisconsin Episode are classified in the Mason Group.

Pre-Illinois Episode Deposits

Pre-Illinois episode glaciation occurred more than 500,000 years ago, and the associated glacial and proglacial deposits are classified as the Banner Formation. The Yarmouth Geosol is commonly developed into the upper part of these materials. Mapping suggests that the bedrock valleys were almost entirely filled with Banner Formation materials by the end of the pre-Illinois episode, as evidenced by the flat upper surface of the Banner Formation across the valleys (fig. 11-3C). The Banner Formation ranges from more than 150 feet thick in a bedrock valley that trends north-south in the eastern part and along the northern border of the quadrangle to more than 25 feet thick at bedrock highs in the southwestern part of the quadrangle (fig. 11-6C). Diamicton units have not been differentiated in the Banner Formation, but the reddish color identified in several borings suggests that one of the units is similar to the Hillery Till Member. All pre-Illinois episode diamictons are highly calcareous.

Extensive and thick sand and gravel deposits are common in the Banner Formation in the quadrangle. The most widespread occur in the eastern part of the quadrangle where about 50 feet overlies the bedrock surface within a bedrock valley. This deposit may be about the same age as the Mahomet Sand Member that occurs in the Mahomet Bedrock Valley to the north. Another extensive sand and gravel body in the west-central part of the quadrangle at the top of the Banner Formation may include some Illinois Episode sand and gravel. The deposit covers an area of about 3 square miles and has a maximum thickness of about 50 feet. In addition, there are discontinuous bodies of thin (<10 feet thick) sand and gravel in the Banner Formation throughout the quadrangle.

Beneath the Banner Formation there are weathered, blue and green (gleyed), silt loam diamictons; laminated, leached silt deposits; and multiple soil layers with organic horizons. These sediments appear to consist of weathered bedrock, some of which was redeposited by gravity and water along slopes on the preglacial landscape. The onset of glaciation may have accelerated slope wash.

Illinois Episode Deposits

Illinois Episode glacial sediments lie above the Banner Formation and were deposited between 125,000 and 180,000 years ago. They are classified as the Glasford Formation. The Sangamon Geosol is commonly developed into the upper part of these materials. These deposits are thicker than 30 feet only in the northwestern part of the quadrangle. They are less than 10 feet thick in several areas in the southern part of the quadrangle (fig. 11-6B). Figure 11-3B shows that the present-day surface of the deposits is relatively flat. It slopes from about 640 feet above mean sea level in the west-central part of the quadrangle to about 600 feet above mean sea level in the southeastern corner. Only one diamicton unit, the gray-brown, silty loam Vandalia Member, was differentiated in this study. Illinois Episode sand and gravel deposits are most prevalent in the northwest and northeast corners of the quadrangle.

Wisconsin and Hudson Episode Deposits and Landforms

The surficial geology and landforms of the Villa Grove Quadrangle are primarily the result of continental glaciation. With the exception of postglacial (Hudson Episode) stream channels and floodplains, the landforms of the quadrangle and the geologic materials at land surface resulted from the Wisconsin Episode glaciation. When the Wisconsin glacier melted back from the area about 18,000 years ago, it left behind a low-relief landscape consisting of (1) large, broad end moraines with low-angle slopes; (2) a slightly undulating till plain; and (3) a flat, low-lying lake plain drained by the Embarras River (fig. 11-7A). The Embarras River originated as

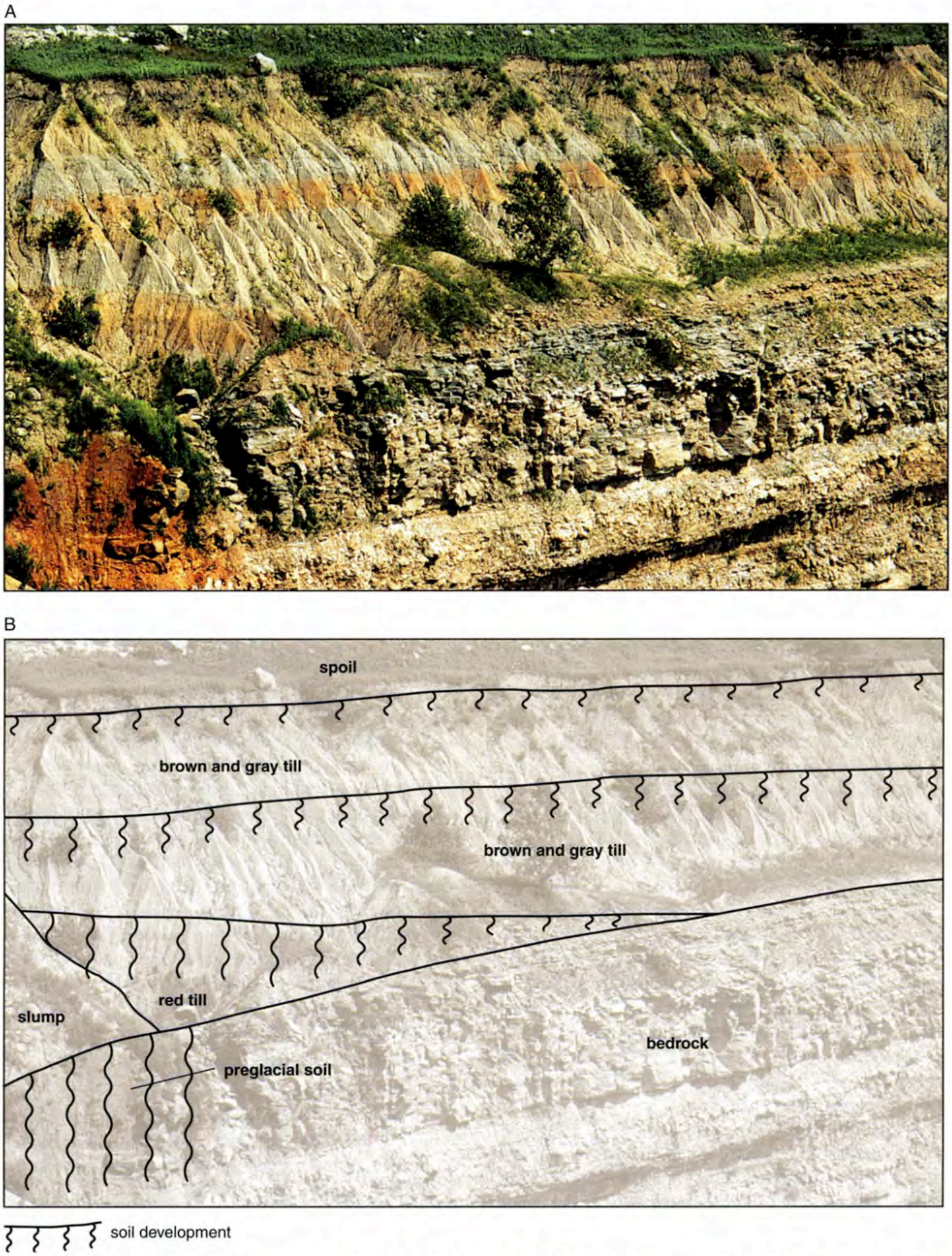


Figure 11-5 Quaternary materials exposed above bedrock at the Tuscola Stone Company quarry. (A) Color photograph and (B) labeled black and white photograph. Photograph shows deposits (mostly till) of the pre-Illinois, Illinois, and Wisconsin glacial episodes. The redder zones are soil zones that formed during four non-glacial episodes including preglacial, interglacial, and post-glacial episodes.

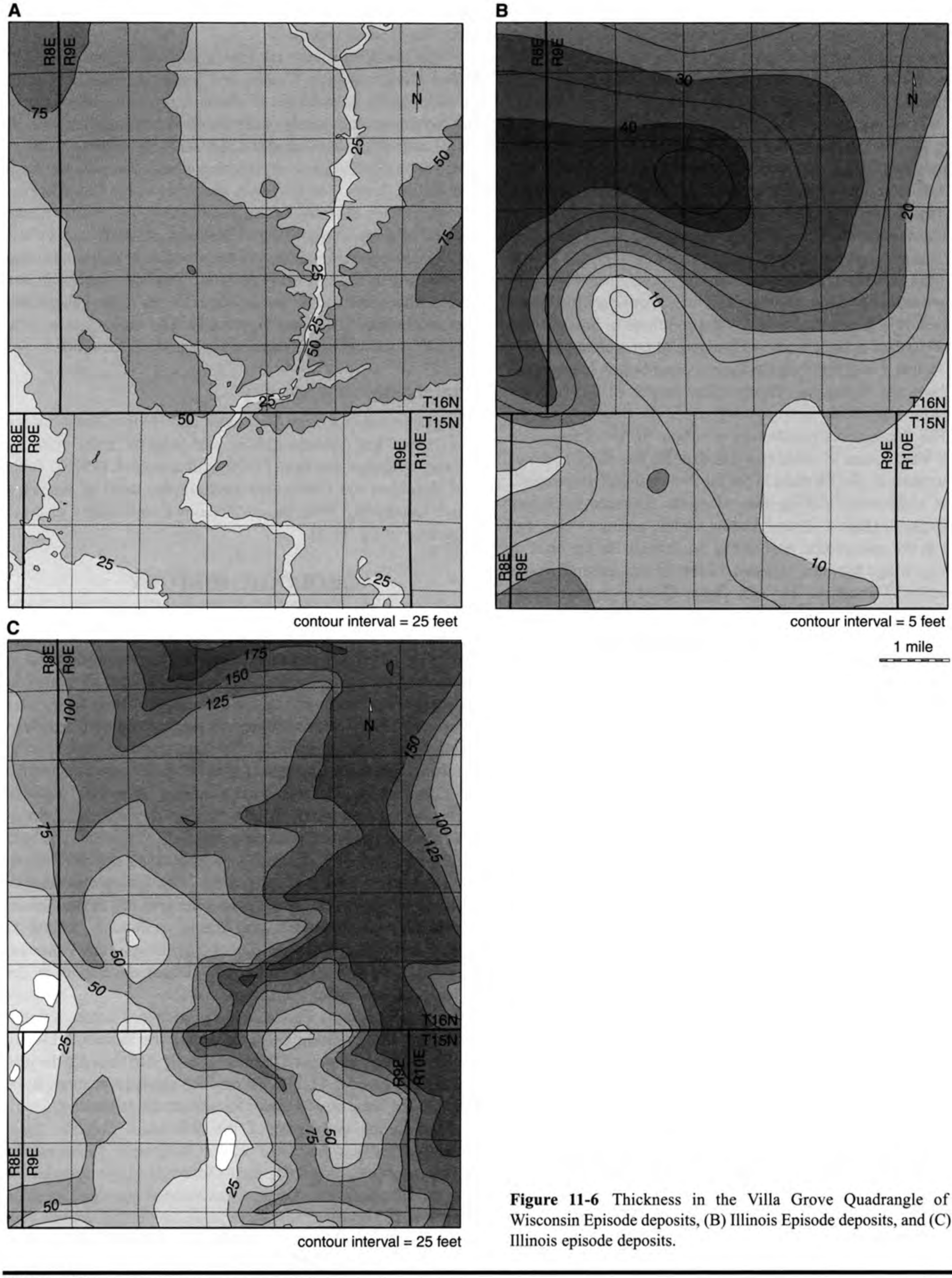


Figure 11-6 Thickness in the Villa Grove Quadrangle of (A) Wisconsin Episode deposits, (B) Illinois Episode deposits, and (C) pre-Illinois episode deposits.

a glacial meltwater stream, whereas some of the smaller tributaries likely developed in postglacial times.

The materials that compose the landforms of the quadrangle are dominated by silt. Except along modern stream channels and floodplains, the landscape is blanketed by 1 to 4 feet of massive, windblown silt, called loess. This loess, classified as the Peoria Silt, was deposited by dust storms that were common in Illinois when glacial meltwater channels were mostly dry and fine sediment was exposed to wind erosion. The postglacial (also called Modern) soil is developed in the Peoria Silt.

The end moraines and till plain are composed of diamicton. This diamicton is interpreted to be predominantly till. It was deposited directly by the glacier with little evidence of reworking by water or gravity. The matrix of the uppermost till consists of about 40% silt. It is dark gray and weathers to brown. This till is classified as the Batestown Member of the Lemont Formation. Below the till of the Batestown Member is a loamy, reddish brown to violet gray till classified as part of the Tiskilwa Formation (fig. 11-4).

The Wisconsin Episode tills are about 50 to 75 feet thick in the West Ridge Moraine but less than 50 feet thick south of the moraine, on the till plain in the north-cental part of the quadrangle, and beneath sloping areas along the Embarras River and its tributaries (figs. 11-2 and 11-6A). A test boring (VG-3, fig. 11-2) in the east-central part of the quadrangle on the crest of the West Ridge Moraine revealed 70 feet of Wisconsin Episode diamictons. Throughout the Villa Grove Quadrangle, the Batestown till is as thick as 50 feet, and the Tiskilwa till is generally thinner than 10 feet.

Deposits of stratified sand and gravel are also found in the Wisconsin Episode sediment of the quadrangle. These deposits are interpreted to be outwash deposited by glacial meltwaters or deltaic sand deposited in a glacial lake. Locally, sand and gravel deposits occur at the base of the Wisconsin Episode till (e.g., in the southeastern part of the quadrangle). This deposit would be classified as the lower tongue of the Henry Formation (fig. 11-4).

Part of the southern third of the map area consists of a flat plain (fig. 11-7A), which is dissected by the Embarras River in the central part and the Scattering Fork in the western part (fig. 11-2). This plain is the floor of a former lake, glacial Lake Douglas (fig. 11-7A). The lake formed when meltwater became ponded between the retreating ice margin and the Arcola Moraine, located about 6 miles south of the quadrangle. Glacial Lake Douglas continued to exist as the ice margin melted back from the West Ridge Moraine toward Villa Grove and northward. The glacial Embarras River cut through the West Ridge Moraine, and a delta (fig. 11-7A) formed where the river entered glacial Lake Douglas. The lake plain is underlain by up to 20 feet of laminated (thin-bedded) silt, clay, and fine sand, except in the north-central part where up to 11 feet of stratified medium sand, fine sand, and silt deposited in a delta overlie or take the place of the laminated sediment (fig. 11-7B). The laminated fine sediment is classified in the Equality Formation. Stratified coarser sediment (mostly sand) of the delta is classified as part of the Henry Formation. These deposits, laid down in glacial Lake Douglas, overlie diamicton of the Batestown Member.

The floodplains and terraces along the Embarras River, Jordon Slough, Hackett Branch, and Scattering Fork (fig. 11-2) are underlain by up to 20 feet of stratified and laminated sediment that consists predominantly of silt and sand and lesser amounts of gravel and clay. This laminated and stratified sediment (interpreted to be alluvium) was deposited by postglacial streams, some of it during floods. The alluvium, classified as the Cahokia Formation, overlies other map units, except for the Peoria Silt. Along the base of some slopes adjacent to stream and river valleys is a loosely consolidated sediment (interpreted to be colluvium) that is classified in the Peyton Formation. This silty sediment was eroded from loess and till on the upper slopes of the valleys and then redeposited along the footslopes. The colluvium is silty because its source is a mixture of loess and silt loam till.

Quaternary Stratigraphy

Stratigraphic units for the Wisconsin and Hudson Episodes are after Hansel and Johnson (1996), and units for older episodes are after Willman and Frye (1970) and Lineback (1979). Table 11-1 describes the Quaternary stratigraphic units of the Villa Grove Quadrangle from the surface downward (many of these are shown in fig. 11-4).

GEOLOGIC HISTORY

Prior to the onset of glaciation, the topography of the Villa Grove Quadrangle had considerably more relief than it does today (fig. 11-3D). A bedrock valley that trends north-south in the eastern part of the quadrangle connects with an east-west valley in the northern part of the quadrangle. These valley segments were filled with sediment before the end of the earliest (pre-Illinois) glacial episode. Drilling revealed that, during preglacial times, the lower parts of these valley segments, which are tributary to the westward-trending Mahomet Bedrock Valley, were being fed by slope sediments in which soils developed during times of landscape stability. Outwash sand and gravel was fed into the valley segments as the pre-Illinois episode glacier advanced toward the Villa Grove Quadrangle. Later, as the glacier advanced across the area, till of the Banner Formation was deposited, and glacial sediments tended to smooth out the topography (fig. 11-3C). During the Yarmouth interglacial episode, the Yarmouth Geosol developed in the deposits of the Banner Formation.

The later Illinois Episode glacier advanced across a flatter landscape, locally eroding and truncating the Yarmouth Geosol and leaving behind a much thinner layer of drift than did the pre-Illinois glacier (fig. 11-3B). During the subsequent interglacial episode, the Sangamon Geosol formed on the landscape.

During the early part of the Wisconsin Episode, loess (Roxana Silt) was deposited on the landscape. Subsequently, during the more climatically stable intervals of the episode, the Farmdale Geosol formed in the loess and was reworked by slope processes to form a stratified deposit containing organic-rich sediment (Robein Member). As the Wisconsin Episode glacier

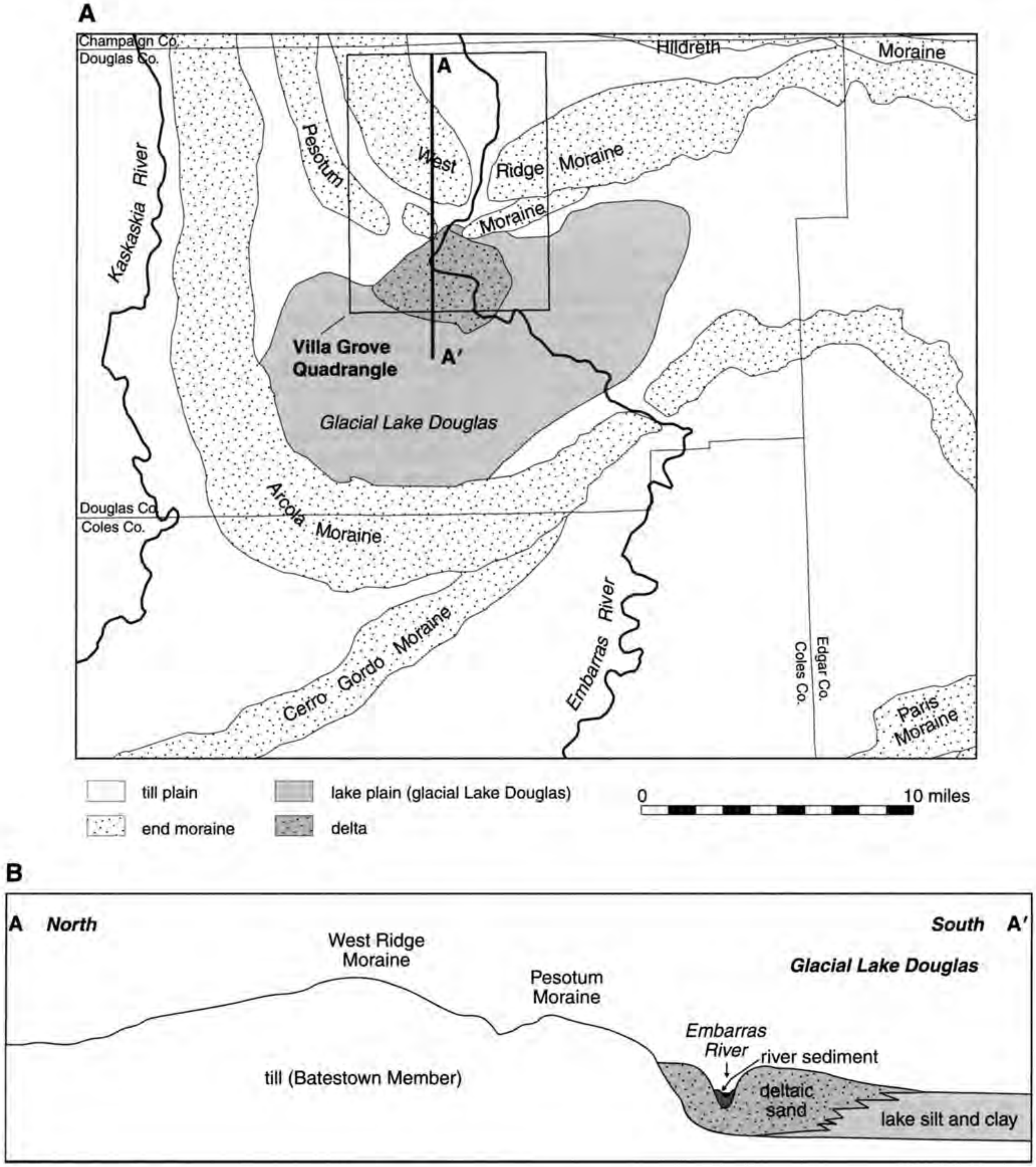


Figure 11-7 Regional setting of the Villa Grove Quadrangle and relationships of surficial materials and landforms. (A) Regional landforms map showing the location of the Villa Grove Quadrangle with respect to end moraines and major meltwater streams in east-cental Illinois. (B) Schematic cross section from north to south across the Villa Grove Quadrangle (see line of cross section in fig. 11-7A) showing relationships among materials, the genetic interpretation of those materials, and their relationship to the landscape. Vertical exaggeration: 110×.

Table 11-1 Quaternary stratigraphic units of the Villa Grove Quadrangle, from the surface downward.

Hudson Episode (postglacial) units

Cahokia Formation

Stratified silt and sand containing lenses of clay and gravel deposited in the channel and floodplain of the Embarras River and its tributaries. The Cahokia Formation consists of stream sediment (alluvium) and is deposited in stream channels eroded into other Quaternary units, especially the Peoria Silt, the Henry and Equality Formations, and the Batestown Member, Lemont Formation.

Peyton Formation

Non- to poorly sorted silt loam and silt loam diamicton that occurs along and at the base of slopes. The Peyton Formation is loose, slope sediment (colluvium). It commonly overlies or intertongues with the Cahokia Formation at the sides of floodplains.

Wisconsin Episode units

Peoria Silt, Mason Group

Light yellow tan to gray, leached, fairly massive silt that blankets the landscape up to a depth of 4 feet, except in the channels and floodplains of the Embarras River and its tributaries. The Peoria Silt is windblown silt (loess) derived from glacial meltwater channels.

Henry Formation, Mason Group

Stratified sand and gravel containing lenses of silt and clay that occurs beneath loess, in glacial meltwater channels beneath post-glacial stream sediments, and in the subsurface as tongues beneath Wedron Group diamicton units (e.g., the Ashmore Tongue beneath the Tiskilwa Formation). The Henry Formation includes the deltaic sand deposited in glacial Lake Douglas and tongues of outwash that were deposited beyond the glacier and subsequently overridden by ice.

Equality Formation, Mason Group

Laminated silt and silty clay that occur beneath loess or beneath the Henry Formation. The Equality Formation consists of the fine-grained lake sediment deposited in glacial Lake Douglas and tongues of lake sediment deposited beyond the glacier and subsequently overridden by ice.

Batestown Member, Lemont Formation, Wedron Group

Brown, gray-brown to gray, calcareous, silt loam diamicton that occurs beneath the Peoria Silt and other Mason Group units. The Batestown Member consists predominantly of uniform till, although minor amounts of diamicton that melted out on top of the glacier or along the ice margin and were later reworked by water and gravity may be present at the top of the unit.

Tiskilwa Formation, Wedron Group

Red-brown, gray-brown, violet-gray to gray, calcareous, loam diamicton that occurs beneath the Batestown Member of the Lemont Formation. The Tiskilwa Formation consists predominantly of uniform till. An erosional contact and stone concentration are present at the top of the unit in some places; tongues of the Peoria Silt and Henry and Equality Formations occur beneath the Tiskilwa Formation in some places.

Robein Member, Roxana Silt, Mason Group

Light to dark brown to black, non-calcareous, stratified to massive silt loam that in many places contains organic debris; locally, the uppermost layer consists of humic material and peat (O horizon of the Farmdale Geosol). The Robein Member consists of debris including silt, sand, wood, peat, and muck that accumulated in poorly drained, low-lying or flat landscape positions. It is in facies relationship with the Roxana Silt and generally contains all or part of the Farmdale Geosol in poorly drained situations.

Roxana Silt, Mason Group

Brownish red to gray, non-calcareous to dolomitic (where thick), relatively massive silt loam. The Roxana Silt is loess that was deposited on upland surfaces during the early part of the Wisconsin Episode; its weathered upper part represents the Farmdale Geosol.

Sangamon Episode unit

Sangamon Geosol/Berry Clay

Reddish brown to gray-green, non-calcareous, highly weathered loam to clay loam to sandy clay loam. The Sangamon Geosol and Berry Clay represent the interglacial soil developed in Glasford Formation diamictons or glacial or non-glacial sorted sediment. It commonly grades upward to the Roxana Silt/Robein Member.

Illinois Episode unit

Glasford Formation (undivided)

Brown to yellow-brown to dark gray, calcareous, silt loam diamicton that may have the Sangamon Geosol (leached) developed in its upper part. Where the geosol is absent, the Glasford Formation occurs below the Tiskilwa Formation or below tongues of the Henry and Equality Formations or the Peoria Silt. Glasford Formation diamictons consist predominantly of uniform till. They commonly have fewer gravel and boulders than the overlying Wedron Group tills. The Glasford Formation may also contain stratified sand, gravel, and silt and laminated silt and silty clay. The former may represent outwash and the latter lake sediment, both deposited beyond the glacier and subsequently overridden by ice. An abrupt contact often exists at the base of the Glasford Formation.

Yarmouth Episode unit

Yarmouth Geosol/Lierle Clay

Dark yellowish brown to gray-brown to olive, non-calcareous, highly weathered loam to clay loam to sandy clay loam. The Yarmouth Geosol and Lierle Clay represent the interglacial soil developed in Banner Formation diamictons or other glacial and non-glacial sorted sediments, or bedrock. An erosional contact commonly separates the geosol from sediment of the overlying Glasford Formation.

Pre-Illinois episode units

Banner Formation (undivided)

Dark gray to reddish brown, non-calcareous, loam to silt loam diamicton that may have the Yarmouth Geosol (leached) developed in its upper part. Where the geosol is absent, the Banner Formation occurs below Glasford Formation diamictons or other glacial and non-glacial sorted sediments. Banner Formation diamictons consist predominantly of uniform till that is highly calcareous. In many places, the till overlies bedrock.

Unnamed sand and gravel

Stratified sand and gravel with silt beds and clay lenses that occur beneath Banner Formation diamictons in a north-south–trending bedrock valley in the eastern part of the quadrangle. The sand and gravel deposit may represent pre-Illinois episode outwash deposited at about the same time as the Mahomet and Sankoty Sand Members found in the Mahomet Bedrock Valley, about 25 miles to the north.

Unnamed diamicton

Blue and green (gleyed), non-sorted to poorly sorted, silt loam diamicton and laminated, leached silt with multiple organic layers that occur beneath Banner Formation diamictons. The diamicton appears to occur on the bedrock surface at the base of slopes (colluvium) as was observed in a boring (VGDH-2, ISGS core 14845, fig. 11-2) in the west-central portion of the quadrangle.

approached the Villa Grove area, outwash and lake sediment were deposited on some parts of the landscape. These sediments (classified as tongues of the Henry and Equality Formations) were later buried beneath tills of the Tiskilwa and Lemont (Batestown Member) Formations, which were deposited by the Wisconsin glacier. As the glacier melted back from the area, more outwash, lake sediment, and loess were deposited on the landscape. These sediments locally form upper tongues of the Henry and Equality Formations and the Peoria Silt. The latter unit blankets the landscape, except where sediment was redeposited in stream valleys and along slopes during the postglacial Hudson Episode (figs. 11-3A and 11-2).

SOCIETAL RELEVANCE

Being able to map and predict the distribution of Quaternary sediments in the Villa Grove Quadrangle is critical because the sediment is thick, and most land use activities take place in these materials. These materials must be excavated for construction of shallow residential and commercial foundations, bridge abutments, sewer and oil or gas pipelines, and other utilities. Chemicals and fertilizers are applied on these materials from agricultural fields and homes and can potentially contaminate groundwater and surface water. Potentially contaminating chemicals can be spilled on the materials from highways and railroad lines. These are also the materials that initially must be removed to extract the bedrock resources at the Tuscola Stone Company quarry, located in the southwestern portion of the quadrangle. Some of the Quaternary materials are also important resources: sand and gravel deposits provide water for farm and village wells, and clayey sediment makes a good cover material for landfills and road overpasses. Understanding the geologic history of the region allows geologists and others to predict where particular types of Quaternary sediments are likely to occur.

REFERENCES

Fraser, G.S., and J.C. Steinmetz, 1971, Deltaic sedimentation in glacial Lake Douglas: Illinois State Geological Survey, Circular 466, 12 p.

Hallbick, D.C., and J.B. Fehrenbacher, 1971, Soil survey of Douglas County, Illinois: Champaign, Illinois, U.S. Department of Agriculture, Soil Conservation Service in cooperation with Illinois Agricultural Experiment Station, 81 p.

Hansel, A.K., R.C. Berg, and C.C. Abert, 1999, Surficial geology map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-SG, scale 1:24,000.

Hansel, A.K., and W.H. Johnson, 1996, Wedron and Mason Groups—Lithostratigraphic reclassification of the deposits of the Wisconsin Episode, Lake Michigan Lobe area: Illinois State Geological Survey, Bulletin 104, 116 p.

Lineback, J.A., 1979, Quaternary deposits of Illinois (map): Illinois State Geological Survey, scale 1:500,000.

Luman, D.E., and A.K. Hansel, 1999, Digital orthophoto image map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-OI, scale 1:24,000.

Weibel, C.P., 1999, Topographic map of the bedrock surface, Villa Grove Quadrangle, Douglas County, Illiois: Illinois State Geological Survey, IGQ Villa Grove-BT, scale 1:24.000.

Willman, H.B., and J.C. Frye, 1970, Pleistocene stratigraphy of Illinois: Illinois State Geological Survey, Bulletin 94, 261 p.

Chapter 12

Drift Thickness and Bedrock Topography

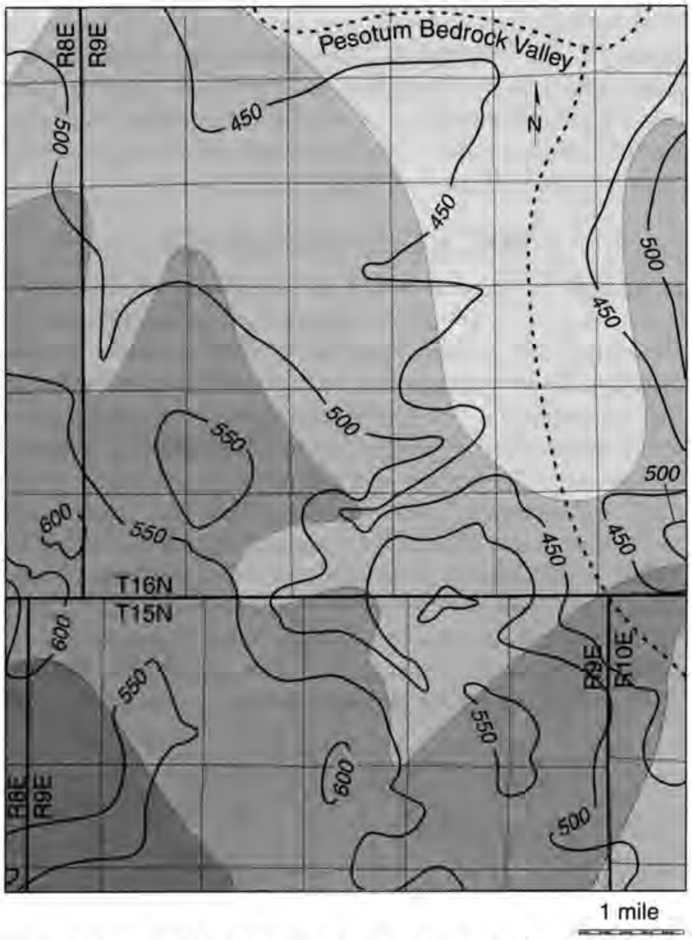
C. Pius Weibel

The earth material that occurs below the land surface and above bedrock is often called drift or unconsolidated deposits. As Piskin and Bergstrom (1975) noted, the terms technically are not synonymous. *Drift* specifically refers to till, outwash, and lacustrine deposits that were deposited by Pleistocene glaciers or by glacial meltwater, but does not include loess (windblown deposits that formed during glaciation) and pre- and postglacial deposits, such as Holocene alluvium. The terms *unconsolidated deposits* or *unlithified deposits* are not entirely appropriate either because in places some earth material is consolidated or lithified, particularly with increasing depth. A more general definition of drift, however, was used for this study of the Villa Grove Quadrangle because most of the material above bedrock in Illinois, and in much of the Midwest, is composed of material deposited by glaciers during the Pleistocene. By this definition, drift includes all of the earth material occurring above bedrock (Bates and Jackson 1987). Drift is considered to be of Quaternary age, which includes both Pleistocene and Holocene deposits.

PROCESSES AND FACTORS GOVERNING DRIFT THICKNESS

Drift thickness is derived by determining the difference between elevations of the land surface and the bedrock surface. The formation of these surfaces is primarily influenced by two important geological processes: deposition and erosion. In the Villa Grove Quadrangle, the bedrock surface is the top of the lithified strata that were deposited during the Paleozoic Era. A very long interval of erosion removed all of the post-Pennsylvanian strata and some of the Pennsylvanian and pre-Pennsylvanian strata from the quadrangle. This interval of erosion, which probably began in the late Tertiary (Kempton et al. 1991) or earlier, resulted in a (now buried) surface consisting of prominent uplands and bedrock valleys (fig. 12-1). The east-west–trending Pesotum Bedrock Valley, a tributary to the Mahomet Bedrock Valley, straddles the north edge of the quadrangle. A major north-south–trending tributary bedrock valley of the Pesotum Bedrock Valley traverses most of the eastern half of the quadrangle.

The very long period of erosion probably ceased during the Pleistocene Epoch, when the quadrangle was subjected to multiple glacial advances and retreats. Regionally, glaciation began less than 1 million years ago (Miller et al. 1994). Glacial ice most recently melted from the quadrangle area about 18,000 years ago (Hansel and Johnson 1996).



—— bedrock surface elevation; contour interval = 50 feet

- - - - axis of buried bedrock valley

400–450 feet	500–550 feet
450–500 feet	550–600 feet

Figure 12-1 Topography of the bedrock surface in the Villa Grove Quadrangle. Elevation contour lines are modified from Weibel (1999). Shaded areas are from the regional study by Herzog et al. (1994). The Pesotum Bedrock Valley traverses the north edge of the quadrangle before trending to the northwest and eventually joining the Mahomet Bedrock Valley about 20 miles to the northwest. Within the quadrangle is a north-south tributary to the Pesotum valley, which was not well defined in the regional study by Herzog et al. (1994).

Glaciers can both erode and deposit material. The dominance of one process or the other generally is controlled by (1) the topography and lithology of the pre-existing land surface beneath the glacier, (2) the local dynamics of the glacier (flow direction, type of flow), (3) proximity of the area to glacial margins, and (4) climatic conditions. Determining which process was dominant at a site during each glacial episode is difficult,

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

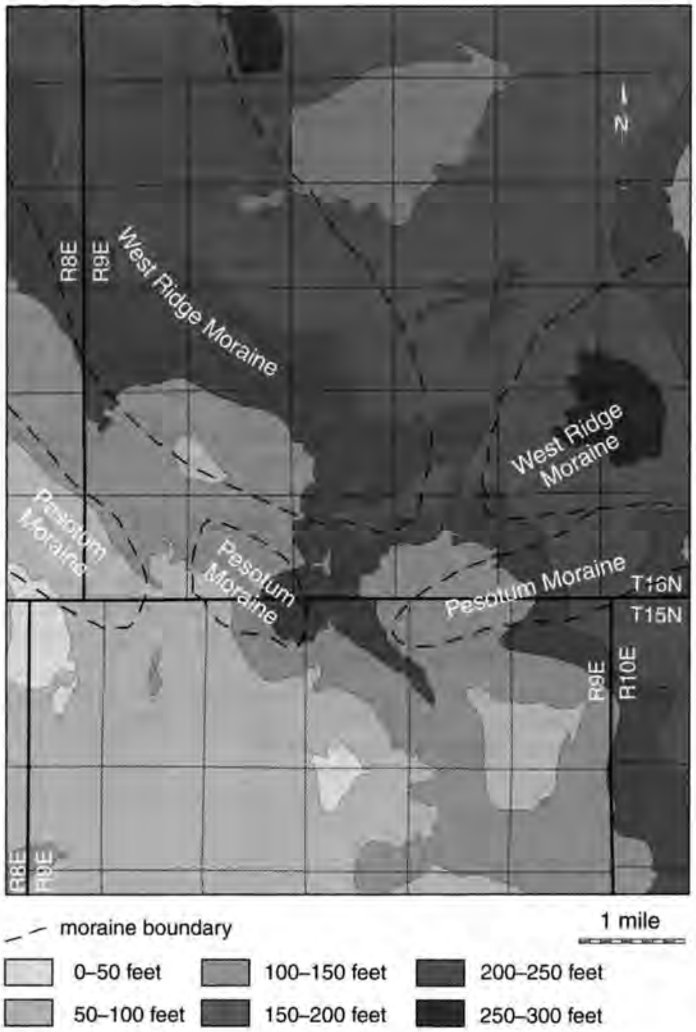


Figure 12-2 Drift thickness in the Villa Grove Quadrangle. Shaded areas are modified after Weibel and Abert (1999). A comparison of these isopachs and the moraine boundaries (from Hansel et al. 1999) indicates that the underlying irregular surface of the bedrock (fig. 12-1) has the predominant influence on drift thickness.

especially for older glacial episodes. In this quadrangle, deposition from the most recent glaciation is indicated by the two end moraines of the Wisconsin Episode, the West Ridge and Pesotum Moraines (fig. 12-2). The present topography has been influenced by the deposition of these moraines, which form very broad ridges across the quadrangle (Hansel et al. 1999). Most of the landforms in the quadrangle formed during the Wisconsin Episode glaciation (Chapter 11). The highest area is on the West Ridge Moraine in the northwest corner of the quadrangle. Fluvial erosion has been the dominant process in the postglacial episode. The Embarras River, which originated as a glacial meltwater stream, and its tributaries have eroded the relatively low-relief landscape. The landscape has also been modified by soil formation and, most recently, by agricultural and other human activities.

The drift thickness map (fig. 12-2) represents the thickness of all of the Quaternary drift (sediment) that has been deposited over the bedrock. Most variation in drift thickness is due to the irregular surface of the underlying bedrock (fig. 12-1). The modern land surface is flat in contrast to the great relief of the bedrock, but the effects of recent incision by the Embarras River and its tributaries are readily discernible on the drift isopachs as well as on the modern topographic surface. The effect on drift thickness of the two end moraines in the quadrangle (fig. 12-2) is far outweighed by the relief of the bedrock surface. Drift is thickest (more than 250 feet) in the east-central part of the quadrangle and near the quadrangle's north-central edge; it is thinnest (less than 50 feet) in two areas near the Tuscola Stone Company quarry, in the west-central part, and in the south-central part of the quadrangle.

MAPPING METHODS

The bedrock topography map (fig. 12-1) is based on data derived from well records in the Geological Records Unit of the Illinois State Geological Survey. The wells include water, petroleum, coal, and stratigraphic borings. The contour map was produced using Dynamic Graphics' EarthVision (EV) software. Location and elevation data were entered, a grid of the surface was produced using a cell size of a length just greater than 700 feet, and the grid was contoured. The contoured grid was manually edited using EV's graphic editor to produce a more geologically realistic surface. The drift thickness map (fig. 12-2) also was produced using EV software to calculate the difference between digital grids of the elevation of the bedrock surface and the elevation of the land surface (from USGS topographic data). The resulting drift thickness grid was contoured using EV software and was converted to an exportable format. ARC/INFO software was used for a final refining of the contours of the bedrock topography and drift thickness maps.

USE OF 1:24,000-SCALE QUADRANGLE MAPS

Mapping the topography of the bedrock surface, understanding the processes and timing of erosion and deposition, and determining the thickness of drift material above the bedrock are all critical components of a three-dimensional, 1:24,000-scale geologic mapping program. Many areas of the state have not yet been mapped at this scale, and, in these areas, the user must use statewide or other small-scale maps. To allow comparison between the Villa Grove Quadrangle maps and regional maps, figure 12-1 includes data from the Buried Bedrock Surface of Illinois map (Herzog et al. 1994). Interpretations on the 1:24,000-scale maps (shown at 1:75,000 scale in figs. 12-1 and 12-2) are of greater detail and accuracy than on the statewide map of the area (Herzog et al. 1994).

The bedrock topography map is useful for (1) delineating buried bedrock valleys, where sand and gravel deposits commonly form very productive aquifers, (2) predicting depth to the top of bedrock for drilling operations and geophysical surveys, and (3) predicting amount and distribution of shallow economically significant rocks (shallow coal, limestone, and dolomite deposits). The relief of the bedrock surface (valleys versus uplands) also affects the types of bedrock that occur at the bedrock surface. The Geological Map of the Bedrock Surface (Weibel and Lasemi, 2001) consequently is invaluable as a base map for detailed mapping of the bedrock geology and can also be used to indicate flow patterns and recharge/discharge pathways of drift aquifers, particularly in areas where adjacent bedrock aquifers may communicate with sand and gravel aquifers in the drift.

The Drift Thickness Map (Weibel and Abert 1999) provides information that is useful in searching for sand and gravel layers and aquifers in the Quaternary deposits. In general, the thicker the drift, the greater is the likelihood of encountering buried sand and gravel units. The map also is useful for predicting the depth to bedrock, particularly when assessing the feasibility of mining bedrock resources (coal, limestone, and dolomite).

REFERENCES

Bates, R.L., and J.A. Jackson, eds., 1987, Glossary of geology, 3rd ed.: Alexandria, Virginia, American Geological Institute, 788 p.

Hansel, A.K., R.C. Berg, and C.C. Abert, 1999, Surficial geology map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-SG, scale 1:24,000.

Hansel, A.K., and W.H. Johnson, 1996, The Wedron and Mason Groups—A lithostratigraphic reclassification of the deposits of the Wisconsin Episode, Lake Michigan Lobe area: Illinois Geological Survey, Bulletin 104, 116 p.

Herzog, B.L., B.J. Stiff, C.A. Chenoweth, K.L. Warner, J.B. Sieverling, and C. Avery, 1994, Buried bedrock surface of Illinois: Illinois State Geological Survey, Illinois Map 5, scale 1:500,000.

Kempton, J.P., W.H. Johnson, P.C. Heigold, and K. Cartwright, 1991, Mahomet Bedrock Valley in east-central Illinois—Topography, glacial drift stratigraphy and hydrogeology, *in* W.N. Melhorn and J.P. Kempton, eds., Geology and hydrogeology of the Teays–Mahomet Bedrock Valley System: Boulder, Colorado, Geological Society of America, Special Paper 258, p. 91–124.

Miller, B.B., R.W. Graham, A.V. Morgan, G.M. Noton, W.D. McCoy, D.F. Palmer, A.J. Smith, and J.J. Pilny, 1994, A biota associated with Matuyama-age sediments in west-central Illinois: Quaternary Research, v. 41, p. 350–365.

Piskin, K., and R.E. Bergstrom, 1975, Glacial drift in Illinois—Thickness and character: Illinois State Geological Survey, Circular 490 (revision of Circular 416), 34 p.

Weibel, C.P., 1999, Topographic map of bedrock surface, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-BT, scale 1:24,000.

Weibel, C.P., and C.C. Abert, 1999, Drift thickness map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-DT, scale 1:24,000.

Weibel, C.P., and Z. Lasemi, 2001, Geological map of the bedrock surface, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-BG, scale 1:24,000.

Derivative Mapping

Chapter 13

Introduction to Derivative Mapping

Richard C. Berg and Zakaria Lasemi

An understanding of the geologic framework and history of the Villa Grove Quadrangle can only be obtained through detailed geological mapping. This understanding is required to accurately delineate the continuity, thickness, and properties of geologic materials. In addition, and perhaps more importantly, a firm understanding of the geologic framework and the processes that formed it enhances the accuracy of predictions of the continuity, thickness, and properties of materials in areas where data are sparse or nonexistent.

The mapping of many surfaces at various depths and the characterization of various physical and chemical properties of geologic materials constitute the core of the three-dimensional mapping program of the Villa Grove Quadrangle. Once these surfaces were mapped and the geologic properties were defined, maps showing the subsurface distribution of geologic units were produced.

Derivative maps, compiled to provide information for specific environmental or resource purposes, present interpretations derived from existing primary data sets. These maps are generally designed to present complex interpretations of geological data in ways that can be readily understood by those who need the information but lack extensive geological training. Chapters 14, 15, and 16 discuss aspects of environmental geology derived from the mapping program, including groundwater resources, aquifer sensitivity, and engineering considerations. These chapters are followed by Chapters 17 and 18 on mineral and coal resources, respectively, of the quadrangle.

A comprehensive geologic mapping program focusing on both environmental protection and mineral resource development issues is essential for policy makers and planners who want to balance their land use decision making by optimizing mineral, groundwater, and other resource extraction while minimizing or preventing environmental degradation. Detailed geologic mapping also provides environmental planners with a more objective basis for making informed decisions. Sensitive regions may require stringent environmental regulation (e.g., areas where thick aquifers are at land surface). However, planners can prevent over-regulation in regions where geologic characteristics reduce the need for protection.

Although not addressed in this volume, the establishment of the geologic framework is also essential for managing biotic resources and for developing derivative map products for planning, restoration, and protection of ecosystems. This information may be important for future work in the Villa Grove Quadrangle, considering the problems with flooding along the Embarras River and proposals to construct wetlands to help mitigate flooding (Kovacic and Gentry 1997).

Geologic maps, in combination with information on topography, soil characteristics, and groundwater and surface water hydrology, can be used to delineate or predict areas where habitats for rare and endangered species are likely to be critical and determine possible impacts of proposed management practices. Geologic deposits at the land surface are the parent materials from which soils are developed. To a large degree, the distribution of the natural flora depends upon, and can be predicted from, variations in geologic parent materials and derived soils. Crop productivity and plant growth potential are equally dependent on geology. Finally, geologic deposits provide direct habitat for fauna. For example, rock-nesting birds as well as burrowing and subsurface-dwelling insects and mammals rely on specific geologic materials or settings. In rivers and lakes, bottom-dwelling aquatic life is dependent on specific substrate conditions dictated by the geologic environment. Many fish, too, require particular bottom conditions to lay their eggs and rear their young. Groundwater seeps and springs—often with unique temperatures and water chemistries—provide local habitats.

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

REFERENCE

Kovacic, D.A., and L.E. Gentry, 1997, Wetlands yesterday and today: The Illinois Steward, v. 6. no. 1, p. 11–15.

Chapter 14

Groundwater Resources

Ross D. Brower

Groundwater in the Villa Grove Quadrangle is available from sand and gravel in glacial deposits and from sandstone, coal, and limestone/dolomite in shallow to medium-depth bedrock. Yields to wells less than 100 feet deep completed in glacial deposits tend to be very small to small, about <1 to 15 gallons per minute (gpm), and range from inadequate to adequate for meeting water supply needs for individual dwellings. An adequate yield provides about 400 gallons per day (gpd) on a year-round basis for a dwelling for four persons. Yields to wells completed in deeper glacial drift in very localized areas may be larger (possibly up to 70 gpm). Well yields from the bedrock may range from very small to moderate (<1 to possibly 300 gpm); the larger yields come from creviced limestones and dolomites in certain areas.

DISTRIBUTION OF GROUNDWATER RESOURCES

Glacial Aquifers

Maps and cross sections show the sequence and distribution of the three major glacial units and the four upper bedrock units in which fresh water may be available for water supply. Detailed descriptions of these units are given in other chapters of this report. Figure 14-1 presents north-south and west-east cross sections that show the scattered distribution of sand and gravel deposits in the glacial units. Thickness of the glacial units (glacial drift) in the Villa Grove Quadrangle is shown in figures 11-6c and 12-2. Figure 14-2 is a map of the rock units forming the bedrock surface, and figure 14-3 is a west-east cross section that shows the gentle eastward dip of these units on the east flank of the north-south–trending La Salle Anticlinorium; its axis lies a short distance west of this quadrangle. The vertical scale of cross sections has been exaggerated to show detail.

Glacial meltwater—released during several advances and retreats of glacial ice over the quadrangle—deposited sand and gravel at scattered locations above and, to a limited extent, within each pebbly clay (diamicton) unit. Diamicton and sand and gravel are the main types of sediment associated with glaciation. Because most sand and gravel was deposited in meltwater drainageways that flowed on, in, under, and in front of the glacial ice, many of these deposits have a lens-like shape that follows the trend of small, fairly widely spaced drainageways. The deeper sands and gravels generally are elongate in northward to northeastward directions, whereas those associated with the middle and upper glacial units have apparent southward trends. The thickest and most widespread sandy deposits are found in the lowest glacial unit, especially at its base where it fills valleys on the bedrock surface. A thin sand at the top of the upper glacial unit covers a broad area in the south-central part of the quadrangle. This sand was deposited in a glacial lake prior to incision of the Embarras River through a moraine that drained the lake. The moraine that formed the dam lies immediately south of the quadrangle.

Figure 14-4 shows the distribution of significant water-yielding sands and gravels found in pre-Illinois, Illinois, and Wisconsin units. The stippled areas in figure 14-4 identify surficial sandy deposits that are seasonally non-water–bearing or that lie in stream valleys subject to frequent flooding. The white or the stippled pattern areas lack significant sand and gravel deposits, and wells completed in the glacial deposits of these areas will have limited to very small yields. Some wells completed in these deposits may not yield enough water to meet daily domestic water supply needs, which are estimated to be about 100 gpd per person on a year-round basis. Wells successfully completed in deposits with limited yield capacity typically require construction with a large-diameter bore. This type of well is open to all slowly permeable horizons lying below the upper construction seal of the well (usually placed 10 to 15 feet below ground surface level). The aggregate yield of all water-yielding horizons open to the well bore may provide enough water to meet the limited supply needs of the well owner.

Bedrock Aquifers

Figures 14-2 and 14-3 and the stratigraphic column in figure 14-5 represent the bedrock units utilized for water supply. Limited quantities of groundwater are available from thin sandstone, coal, and limestone horizons interbedded within non-water–yielding shales that compose the Pennsylvanian System in the eastern three-quarters of the quadrangle. The underlying Borden Siltstone, Chouteau Limestone, and New Albany Shale Group have no water-yielding capacity except for very limited quantities of water from fractures in the thin Chouteau and a thin sandstone in the basal part of the overlying Borden. The largest yield capacity in the bedrock is found in several of the dolomite intervals of the Devonian System and the more deeply buried Silurian System.

Concentrations of dissolved minerals in groundwater generally increase with greater depth to aquifers. Aquifers containing potable water (water usable for human and farm animal consumption) can occur at depths as great as 1,000 feet along the west boundary of the quadrangle; at shallower depths lies water with a total dissolved mineral content of less than 500 mg/L of total dissolved solids (TDS), the recommended upper limit for human consumption. Mineralization increases toward the east,

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

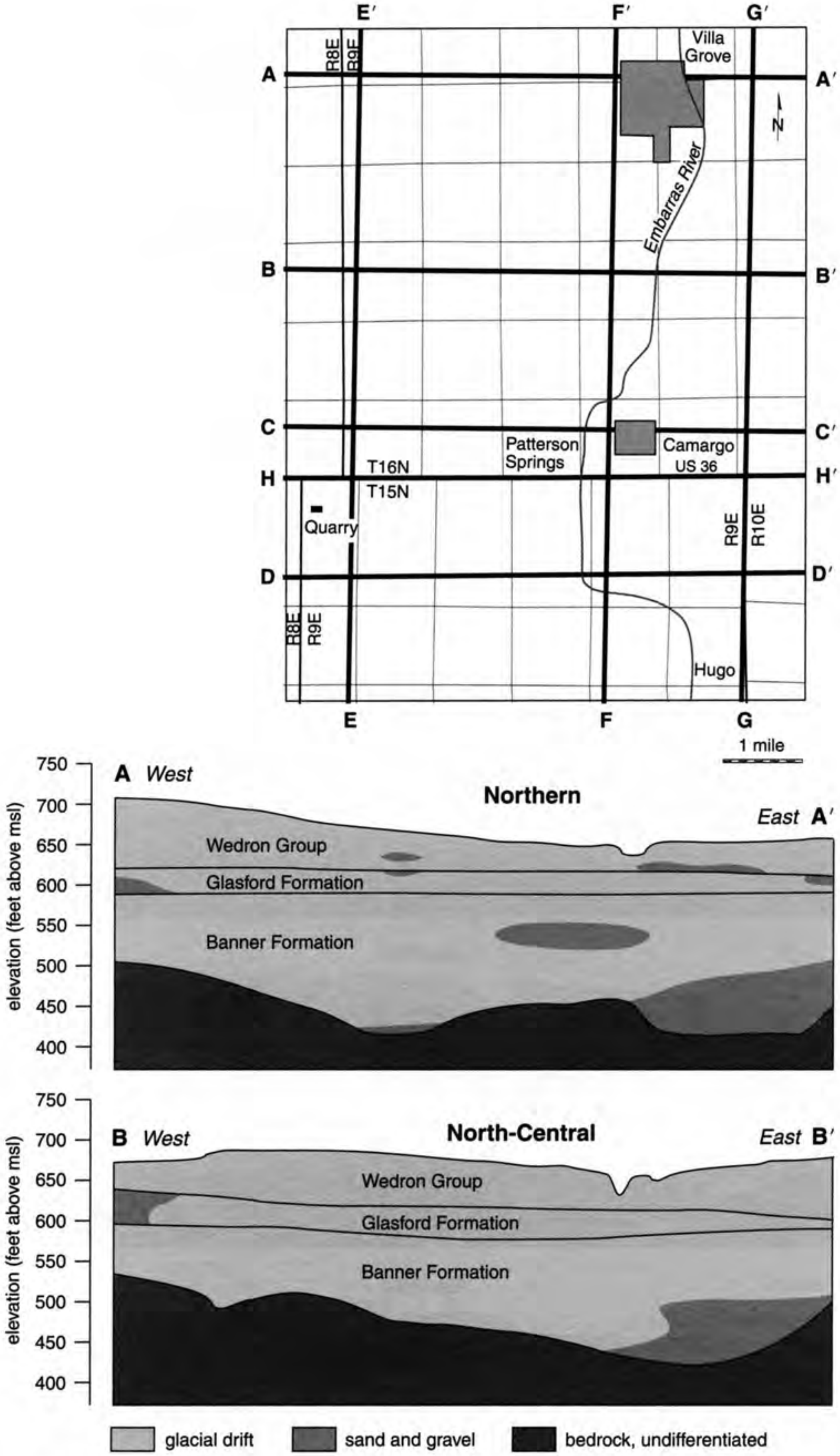


Figure 14-1 Cross sections showing glacial deposits (including sand and gravel) and shallow bedrock surface in the Villa Grove Quadrangle. Cross section H–H′ is given on figure 14-3. (Cross sections by C.C. Abert.)

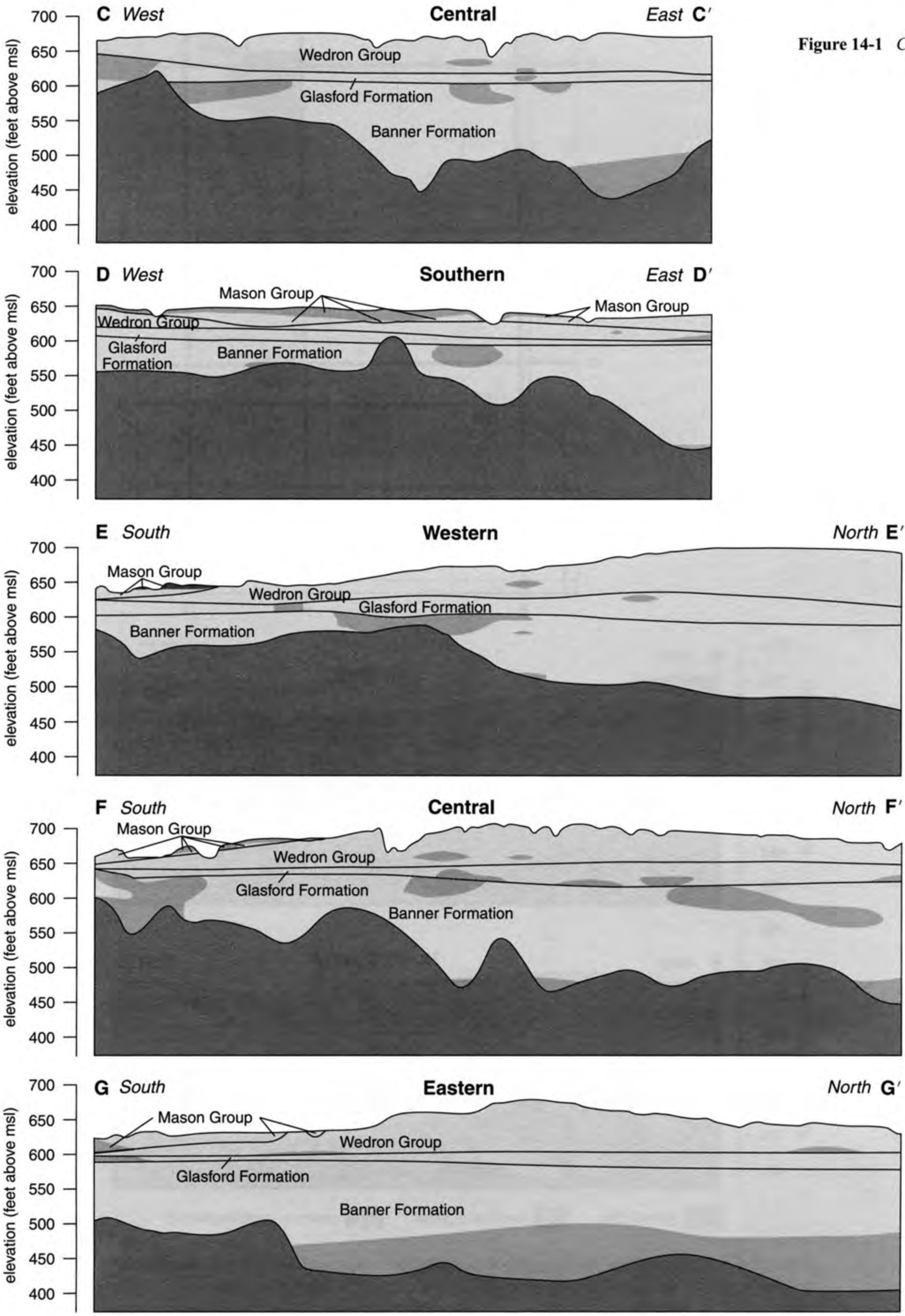


Figure 14-1 *Continued*

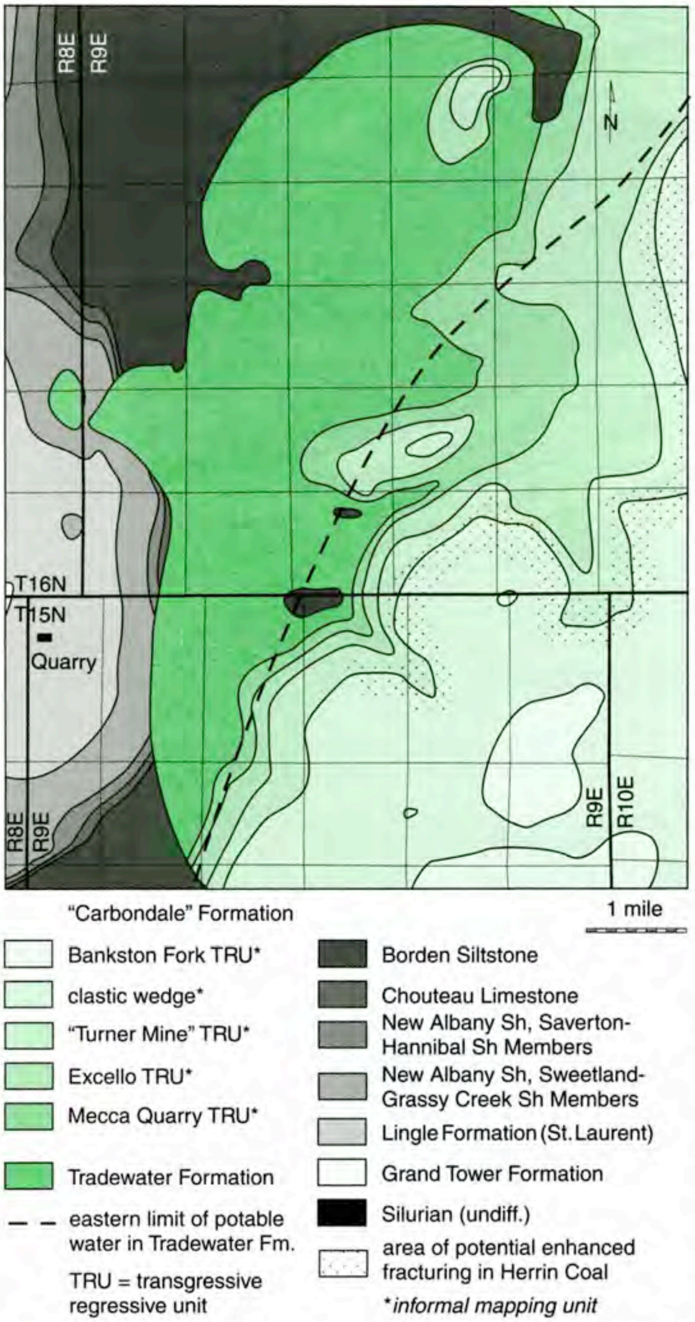


Figure 14-2 Generalized geologic map of the bedrock surface of the Villa Grove Quadrangle (modified from Weibel and Lasemi 2001).

particularly in the southeast quarter of the quadrangle. In the eastern two-thirds of the southeast quarter of the quadrangle, water suitable for drinking may be found only in the upper 200 feet of earth materials. The dashed line in the cross section in figure 14-3 is the approximate transition boundary (3,000 mg/L of TDS) between potable groundwater to the west and non-potable water to the east. In figure 14-6, the dashed line with question marks that is extended to the northeast is a map view of the approximate position of this same boundary for water-yielding horizons in the Devonian units. The extended line of question marks is the approximate boundary where no water quality data exist for the Devonian or the Silurian. The estimated position of this boundary in the Pennsylvanian-age Tradewater Formation is shown in figure 14-2 as a dashed line. If a boundary for 500 mg/L of TDS were drawn on the cross section in figure 14-3, it would lie at a much shallower depth and be displaced westward from the boundary between potable and non-potable water. Toward the southeast corner of the quadrangle, the TDS concentration of the groundwater approaches 10,000 mg/L in all deeper units. In that area, an ISGS test hole encountered brine (water with approximately 12,000 mg/L of TDS) in a basal sandstone (360 foot depth) of the Pennsylvanian age Tradewater Formation.

Groundwater yields from Devonian and Silurian units typically range from small to moderate (5 to possibly 50 gpm). In the western and northern one-third to one-half of the quadrangle, larger yields may be encountered, and yields in excess of 300 gpm may locally be possible from these units on an intermittent pumping basis. Two municipal wells in Villa Grove yield 300 to 600 gpm from the upper unit of the Devonian, which lies below a depth of 600 feet. These wells are pumped on an intermittent basis with an average daily production in 1997 of 264,000 gpd (Illinois Environmental Protection Agency, Public Water Supply Division [IEPA-PWS] database). The produced water has been reported to have a mineral content of 570 ± 80 mg/L of TDS (Illinois State Water Survey and IEPA-PWS records). Similar yields and water quality were noted in several of the wells completed in Devonian and Silurian rocks by the City of Tuscola and by an industrial facilty to the north. However, test holes near Patterson Springs that penetrated the Devonian at slightly shallower depths than the Villa Grove wells encountered relatively low yield capacities and highly mineralized water.

The pattern of increasing TDS concentration in the southeast quarter of the quadrangle suggests several potential causes: (1) reduced permeability in the Devonian and Silurian units in this area and, in particular, in the vicinity of Patterson Springs, (2) structural or erosional control by the La Salle Anticlinorium that restricted freshwater recharge to these rocks during Pleistocene glaciation, (3) an unmapped, eastward-trending structural dislocation in Devonian and Silurian units located near or a short distance north of Patterson Springs, and (4) a combination of all of these factors. Any factor that would restrict entry of fresh water from the surface or circulation of groundwater in the underlying bedrock units would contribute to the presence of highly mineralized groundwater in the southeastern part of the Villa Grove Quadrangle.

AQUIFERS

The thin discontinuous sands, gravels, and silts interbedded with the much more abundant diamictons of the glacial deposits in the Villa Grove Quadrangle have a very limited to moderate capacity to yield water to wells. These deposits are considered aquifers wherever they individually or collectively yield enough water to a well for a water supply. The following discussion describes the character and distribution of these water-yielding deposits that accumulated during each of the three episodes of glaciation.

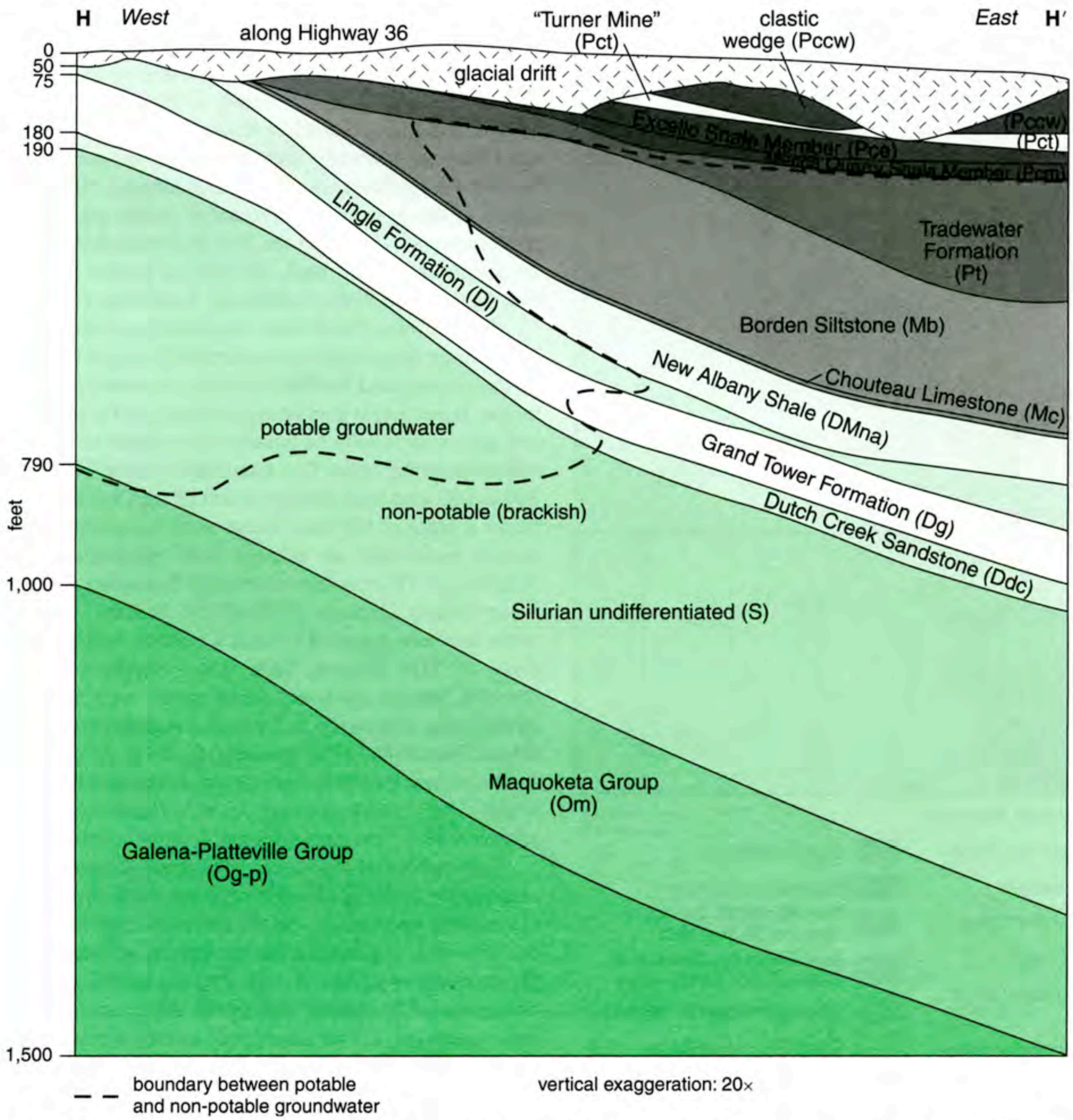


Figure 14-3 Generalized cross section along U.S. Highway 36 showing bedrock, glacial drift, and the boundary between potable and non-potable groundwater (3,000 mg/L of TDS) (modified after Weibel and Lasemi 2001). Vertical exaggeration: 20×.

Glacial Aquifers

Wedron Group The upper glacial unit was deposited during the Wisconsin Episode of glaciation (Chapter 11) as several diamicton units (a mixture of silt, clay, sand, some gravel, and a few boulders) and a few interbedded lenses and thin, discontinuous layers of a water-laid deposit of sand, gravel, and variable amounts of silt. These deposits are often assigned to the Mason Group, a set of deposits contemporaneous to near-contemporaneous with the Wedron Group, but have been included with the Wedron here because they are of minor importance as aquifers.

The cross sections in figure 14-1 show only locally thick, but quite narrow, lens-shaped layers of sand and gravel that were deposited in glacial meltwater drainageways that were widely spaced across this area. Surficial sandy deposits may also be present in some places in the Embarras River valley and cover a broad area in the south where a delta formed in a short-lived glacial lake. The relatively thin (postglacial) alluvium and widely scattered patches of sand and gravel in the river valley and the broad sandy and lacustrine deposits in the south are not significant sources for groundwater supply. At many locations, these deposits are non-water–bearing during the drier seasons of the year, and deposits located in stream valleys are subject to frequent flooding. The distribution of these surficial sand deposits is shown in figure 14-4.

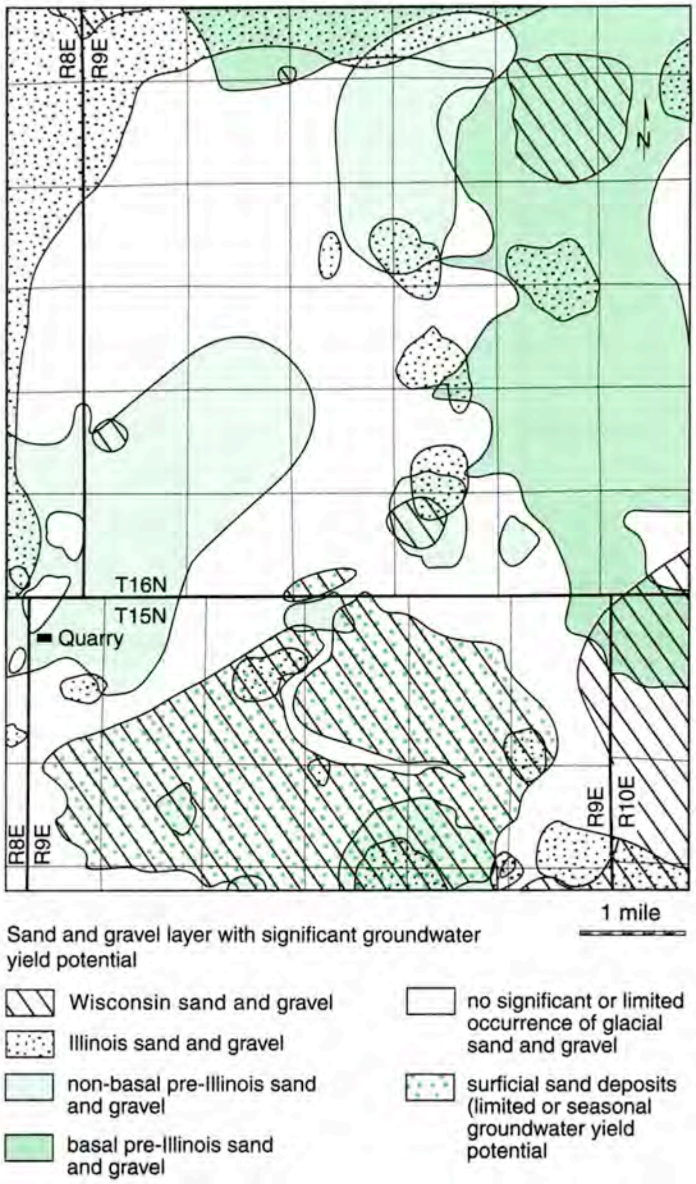


Figure 14-4 Significant sand and gravel layers in pre-Illinois, Illinois, and Wisconsin Episode deposits in the Villa Grove Quadrangle.

The groundwater-yielding capacity of the Wedron is very limited at most locations. Many wells are drilled through the Wedron and completed in underlying glacial units. Wells successfully completed in Wedron deposits typically have a very limited yield. Yield generally declines significantly during drier seasons of the year, and some wells go completely dry seasonally. Most successful wells have a large-diameter well bore that serves as a storage reservoir for groundwater seeping into the well from intercepted, slowly permeable horizons.

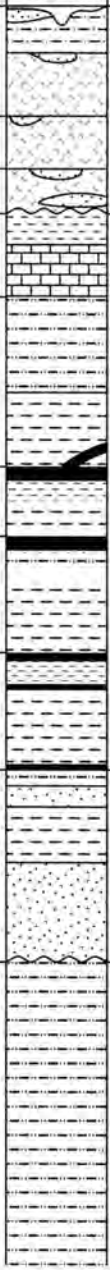
Glasford Formation The underlying Glasford Formation (fig. 14-1), which was deposited during the next older Illinois Episode of glaciation, is the thinnest of the three glacial units in this quadrangle. It is composed of one and possibly two diamicton units; sand and gravel deposits in the Glasford are thin and widely scattered. The greatest thickness of Glasford outwash deposits is found approximately beneath the general trend of the Embarras River valley and along parts of the western and northern borders of the quadrangle. Where present, the sands and gravels composing these deposits are less than 2 to 5 feet thick. Locally, somewhat thicker sand and gravel may be present as narrow, sinuous bands and lenses that were deposited in drainageways that carried meltwater from the glacial ice front. The yield potential of most Glasford water-yielding horizons (aquifers) is also limited, and most wells fully penetrating the 8 to 45 foot thickness of this unit would not encounter a significant water-yielding horizon. Wells drilled in the large white areas in figure 14-4 would have very limited potential or no potential for yielding even a very small domestic water supply on a year-round basis from the Glasford Formation. Wells that do not penetrate an aquifer with sufficient yield in the Glasford may be drilled deeper to find a water-yielding sand and gravel in the underlying Banner Formation.

Banner Formation The basal glacial unit, the Banner Formation, was deposited during the pre-Illinois episode of glaciation (Chapter 11). This unit, which is composed of three or more diamicton units, is highly variable in thickness because it occurs mainly as deposits in preglacial valleys on the bedrock surface. The thickness of this unit ranges from 0 feet over the highest points on the bedrock surface to more than 180 feet in the larger bedrock valleys, as shown in cross section C–C′ of figure 14-1. The rolling topography of the bedrock surface (fig. 10-1; Weibel 1999) was formed on the southern slope of the Pesotum Bedrock Valley, which lies along the north margin of the quadrangle, and on the slopes of the tributary bedrock valley system joining the Pesotum valley from the south.

Sand and gravel deposits in the Banner Formation may be found at several positions (figs. 14-1 and 14-4): (1) A basal outwash, along with lacustrine silts, sandy silts, and clays occur in parts of the deeper bedrock valleys. (2) Non-basal sand and gravel occurs beneath the general trend of the Embarras River and in a limited area along and near the central part of the western border of the quadrangle. The occurrences of Banner sand and gravel tend to be thicker and somewhat more areally extensive than those found in the overlying Glasford Formation or Wedron Group. Locally, Banner sand and gravel deposits, particularly the basal sand and gravel deposits, are associated with thin to relatively thick lacustrine and fluvial silt deposits. These silts have a limited to very limited water-yielding potential. Wells completed in sand and gravel with interbedded silt layers may continue to produce small to large quantities of sediment following well development.

The sustained yield of wells finished in the Banner Formation can range from very limited to over 35 gpm. Larger yields may be available on an intermittent pumping basis. The greatest yield capacity from Banner Formation sand and gravel deposits is found at scattered sites along the bedrock valley system that extends northward from the vicinity of Camargo.

Wherever Banner sands and gravels are in contact with water-yielding bedrock units, there is a potential for enhancement of the yield capacity of both units. Village of Camargo Well No. 1, which is finished in the Herrin Coal at a depth of 165 feet, appears to be an example of this phenomenon. Cross

Unit Name	Graphic Column	Description	Thickness (feet)	Lithostratigraphic Nomenclature	Series	System	Aquifer Characteristics
Mason Group		surficial outwash above lacustrine deposits	0–25	WISCONSIN	Pleistocene	Quaternary	seasonal, very limited aquifer potential
Wedron Group		diamictons and discontinuous lenses of sand and gravel	0–75				non-aquifer with very limited aquifer potential in thin widely scattered sand and gravel
Glasford (Qg)		diamictons and discontinuous lenses of sand and gravel	8–45	ILLINOIS			(same as for Wedron)
Banner (Qbn)		diamictons, interbedded sand, gravel, silt outwash, and lacustrine deposits	0–180	PRE-ILLINOIS			non-aquifer with limited aquifer potential in thin interbedded sand and gravel
Bankston Fork TRU (Pcb)		shale, gray limestone, light gray, fine-grained, argillaceous	0–30	Bankston Fork Limestone ("Carbondale" Formation (0–190 ft))	Middle	Pennsylvanian (Sub-System); Carboniferous	non-aquifer with limited aquifer potential in thin coals and sandstones, locally extensive fracture development in coals enhances yield capacity
clastic wedge (Pccw)		bioturbated at top siltstone, gray to greenish gray, argillaceous, shale, gray, silty at top	0–80				
"Turner Mine" (Pct)		coal, black, splits at southern edge of quadrangle claystone, dark gray, carbonaceous shale, black, fissile coal, black	0–55	Herrin Coal Turner Mine Shale Springfield Coal			
Excello TRU (Pce)		claystone, very dark gray siltstone, calcareous shale, gray, silty, calcareous at base shale, black, fissile coal, black	0–35	Excello Shale Houchin Creek Coal			
Mecca Quarry TRU (Pcm)		claystone, gray coal, black, thin shale, gray, weakly calcareous at top shale, dark gray shale, black, fissile coal, black	0–35	Mecca Quarry Shale Colchester Coal			
Tradewater Formation (Pt)		siltstone, light gray, carbonaceous sandstone, tan to light gray, very fine- to fine-grained shale, very dark gray with scattered sandstone interbeds sandstone, gray, very fine- to medium-grained	0–250	Tradewater Formation	? Lower	Pennsylvanian (Sub-System); Carboniferous	non-aquifer with sandstones capable of yielding small quantities of water
Borden Siltstone (Mb)		siltstone, light greenish gray, bioturbated	0–350	Borden Siltstone	Middle	Mississippian (Sub-System); Carboniferous	non-aquifer

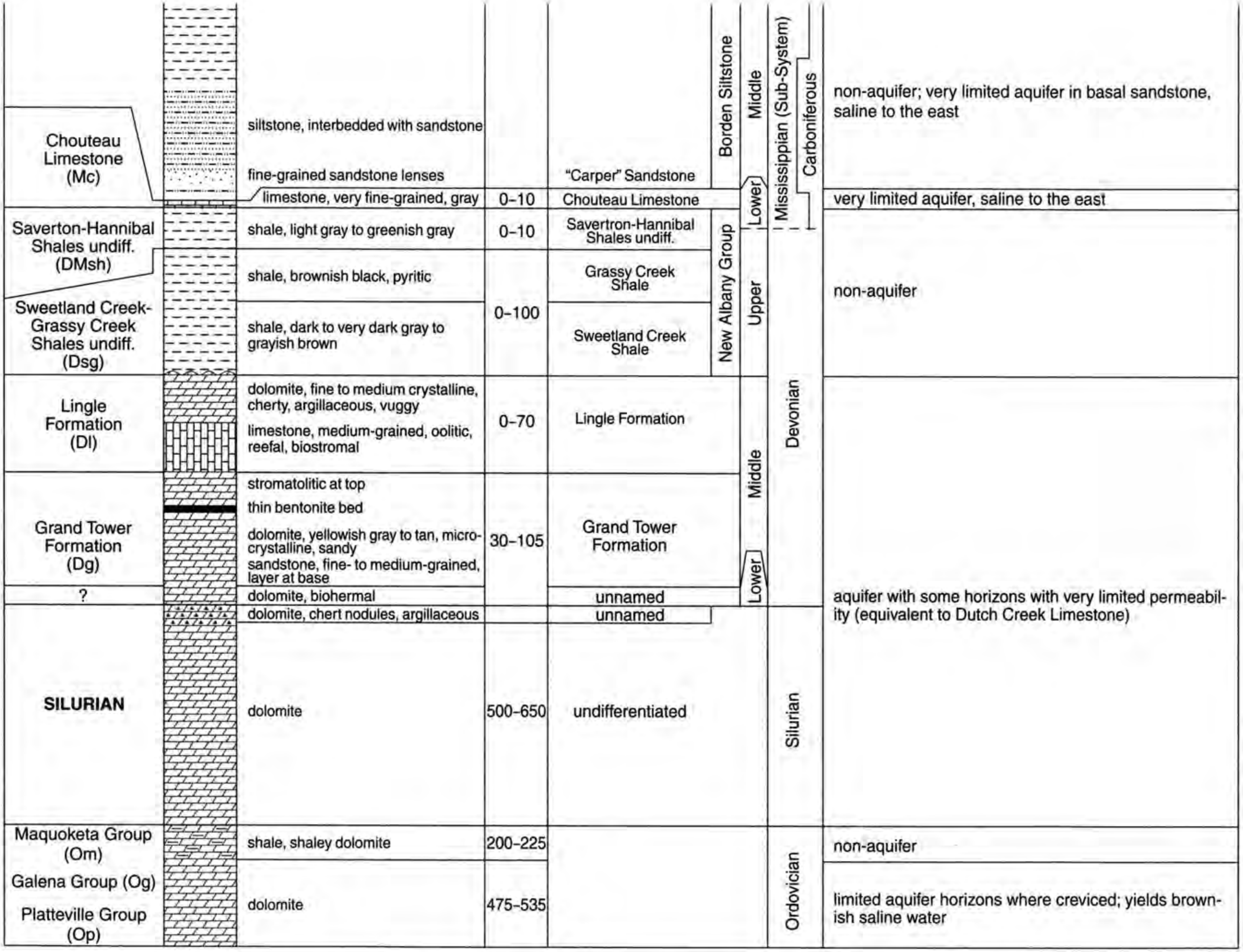


Figure 14-5 Stratigraphic column for glacial deposits and shallow bedrock of the Villa Grove Quadrangle (modified from information presented in Chapters 7, 8, 10, and 11). TRU, transgressive-regressive unit.

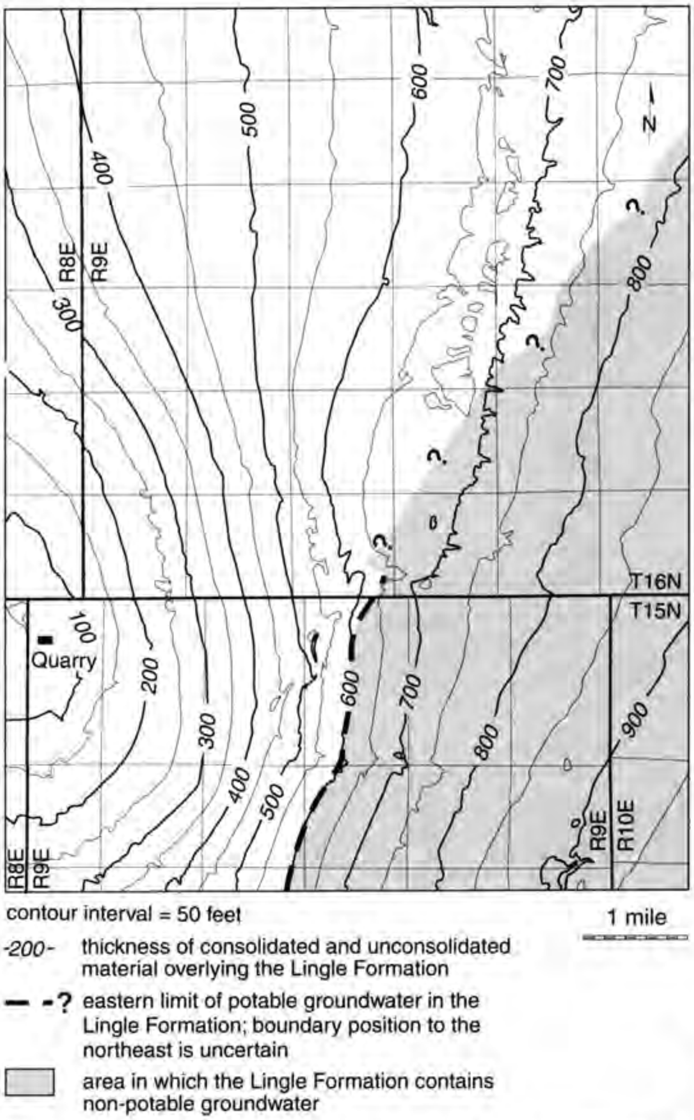


Figure 14-6 Total thickness map of consolidated and unconsolidated materials overlying the Lingle (St. Laurent) Formation in the Villa Grove Quadrangle. Also shown is the transition boundary between potable (to the west) and non-potable (to east) groundwater in the Devonian; boundary line is roughly estimated to the northeast (modified from Lasemi et al. [Chapter 17]).

section E–E′ in figure 14-1, which was constructed a short distance west of Village of Camargo Well No. 1, shows sand and gravel associated with diamicton units that form the upper part of the Banner Formation at about the same elevation in the valley fill as the Herrin Coal, which crops out on the nearby bedrock valley slope that lies between the well site and the line of the cross section (fig. 14-2). Figure 14-2 shows the outcrop pattern of the unit (labeled Turner Mine) of which the Herrin Coal is a part. The unusally high yield capacity exhibited by this well may be attributed to both enhanced development of fractures in the coal near its outcrop and contact of the outcropping coal bed with water-yielding outwash in the Banner Formation valley fill.

Bedrock Aquifers

Pennsylvanian System Some aquifers are found in the Pennsylvanian rocks in the quadrangle (Weibel 1999). Figure 14-2 shows the distribution of Pennsylvanian units on the bedrock surface, beginning with the basal contact of the Tradewater Formation resting on the older Mississippian age bedrock (Borden Siltstone) near the west and north margins of the quadrangle. To the east, successively younger Pennsylvanian units form the bedrock surface, with a unit near the top of the "Carbondale" Formation present along most of the east margin of the quadrangle. The Tradewater Formation covers a broad area in the west and north, where it dips very gently eastward to southeastward. The dip increases somewhat along the west margin of the outcropping of the "Carbondale" Formation. Non-water–yielding shales are the predominant lithology in the Pennsylvanian rocks. Meager to small quantities of water (up to several gallons per minute) may be available from the thin sandstones, sandy siltstones, limestones, and coals interlayered in the shales in these rocks. Sandstones are most prevalent in the Tradewater, whereas limestones and coals are more common in the "Carbondale" (Chapters 10 and 13).

The potential yields of wells in the Pennsylvanian rocks are limited by the thinness of the deposits and the small particle size of the sandstones, the lack of significant fracture development in all of these rocks (particularly in the limestones and coals), or both. The sandstones vary considerably in thickness and texture (particle size distribution) from place to place and locally grade into finer or coarser grained rock. Sandstone may grade horizontally into siltstone, and the siltstone may grade into shale. The most productive and widely distributed sandstone is found a few tens of feet above the base of the Tradewater Formation. Yields from this sandstone, which is 10 feet to possibly 25 feet thick, may be adequate for domestic water supply needs at individual dwellings. This unit, however, only contains potable water where the Tradewater is exposed on the bedrock surface; elsewhere in the quadrangle it contains brackish to saline water.

Although limestones tend to be quite widely distributed, they offer, at best, only meager potential for yielding water to wells because their narrow fractures are tight, generally widely spaced, and not significantly enlarged by dissolution, particularly in argillaceous (clayey) limestones. Coals in the Pennsylvanian rocks are also thin, but have a slightly greater degree of fracture development than the limestones, particularly along slopes of the buried bedrock surface.

Fractures are locally enhanced near the Camargo Well No. 1, which lies close to coal outcropping. This well was constructed in the Herrin Coal in 1956 to a depth of 165 feet and was test-pumped at a rate of 37 gpm for 6 hours. Yield potential from this coal probably will decrease fairly rapidly away from the face of the coal outcrop in relation to the decline in the size, number, and degree of interconnection of fractures. Thus, the most water-productive areas in the Herrin Coal lie adjacent to the valley slope and the sustained yield from the coal bed increases where glacially deposited sand and gravel valley fill is in contact with the outcropping coal. The stippled pattern in figure 14-2 indicates where fracture development is probably greater in the Herrin Coal.

Mississippian-Devonian Systems The Borden Siltstone, Chouteau Limestone (a relatively thin unit), and the various units of the New Albany Shale Group, which includes both Mississippian and Devonian units (Chapter 8), compose 470 feet of non-water–yielding rock. Very small quantities of water may be found in the Chouteau Limestone where it is fractured and in a thin sandstone near the base of the overlying Borden Siltstone (fig. 14-5). The water in these horizons has a fairly high total dissolved mineral content and rapidly becomes more mineralized a short distance east of the outcropping of these units on the bedrock surface. Therefore, because of the water's high levels of mineralization and the insignificant yield capacity, these units are not considered a source for water supply throughout the quadrangle.

Devonian System Significant water-yielding horizons are found in the upper and lower dolomite units of the Devonian System. The upper dolomite unit, the Lingle (St. Laurent) Formation, is 60 ± 5 feet thick, but is thinner where eroded over the crest of the La Salle Anticlinorium and in localized areas to the east (Chapter 8). The gentle eastward dip of this unit and the thickness of bedrock and glacial drift between it and the land surface are shown in figure 14-6. Note the increase in dip in the Patterson Springs area (Sec. 33, T16N, R9E). The common fractures and solution features are the principal source of water. Interstitial pores in this unit also yield water. A relatively thick interval (90 ± 15 feet) of the Grand Tower Formation, a dolomite with a very limited capacity to yield water, separates the Lingle (St. Laurent) from the basal water-yielding horizon of the Devonian interval, which includes a thin dolomitic sandstone (Dutch Creek Sandstone equivalent) and an underlying biohermal dolomite (Chapter 8). The elevation above sea level on the upper surface of the Grand Tower Formation is shown on the structural contour map (fig. 14-7). The two units composing the basal interval have a combined thickness range of 5 to 35 feet and may provide a small to moderate yield capacity.

Yields from the Devonian rocks may range from 5 to 150 gpm, and a few wells may yield more than 300 gpm, as has been reported for the wells supplying water for the Village of Villa Grove and those formerly supplying the City of Tuscola. Note also that large quantities of water have been and will continue to be pumped from the quarry. Figure 14-6 shows the position of the transitional boundary (3,000 mg/L of TDS) between potable water to the west and non-potable water to the east-southeast. A short distance east of this line and, in particular, in the southeast quarter of the quadrangle, the level of mineralization in the groundwater increases rapidly to the east. The Devonian also dips to the east at a moderate rate and rapidly becomes more deeply buried. Near the southern half of the east edge of the quadrangle, the groundwater in the Devonian is likely to have a mineral content of approximately 10,000 mg/L of TDS.

Silurian System At the top, this system includes a few tens of feet of cherty dolomite, a thick interval of Moccasin Springs Formation (consisting of an upper dolomite and lower argillaceous dolomite) in the middle, and the basal St. Clair Limestone

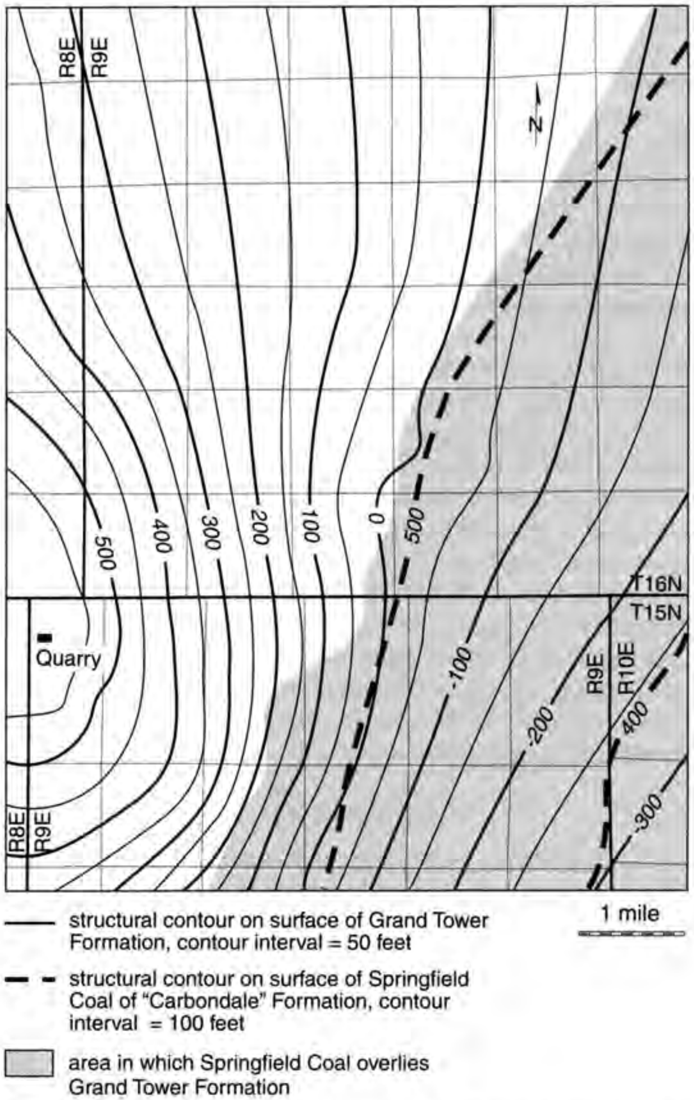


Figure 14-7 Upper surface of the Grand Tower Formation and Springfield Coal of the "Carbondale" Formation in the Villa Grove Quadrangle. Contour lines are feet above mean sea level (modified from Weibel and Lasemi 2001).

(Chapter 7). Water-yielding horizons have been encountered in the massive dolomite composed of the upper part of the Moccasin Springs, possibly in the thin cherty dolomite horizon overlying the Moccasin Springs, and in parts of the St. Clair Limestone. The few data describing the water-yielding character of this system of rocks suggest that yields could range from a few tens of gallons per minute to 50 gpm. In the western one-third to one-half of the quadrangle, yields up to 150 gpm may be possible. Locally, larger quantities may be available, but pumping duration at high discharge rates may be limited.

Well construction records at the Illinois State Geological Survey indicate that prior to development of the Tuscola Stone Company quarry, piezometric levels were typically near or above the bedrock surface and declined somewhat to the west and northwest toward wells operated by the City of Tuscola for municipal water supply and by local industry located farther north. As the quarry operation has extended to greater depths, dewatering has produced a cone of depression that is increasing in size in the Devonian and Silurian units. Groundwater flow beneath the cone of depression in these units is toward the quarry. Water levels have been declining in private wells located near the quarry, and at least one well required completion to a greater depth when the water level fell below the bottom of this relatively shallow well (personal communication with well driller 1996).

In the western and northwestern parts of the quadrangle, groundwater mineralization is moderate and near the upper end of the range that is suitable for drinking water purposes. Most wells penetrating the Silurian are also open to the Devonian; yields are thus a blended water of both the Devonian and Silurian. The Silurian probably has a somewhat greater level of mineralization both with depth and to the east, particularly to the southeast. The mineralization level in the Silurian toward the southeastern margin of the quadrangle is expected to be slightly above 10,000 mg/L of TDS.

Water from a well constructed on a lift near the bottom of the quarry was reported by the driller to increase somewhat in mineralization as deeper water-yielding horizons were encountered during drilling in the Silurian rock interval. The well flowed and the water level became higher as the well was drilled deeper (personal communication with on-site driller).

SUMMARY

The availability of potable groundwater in the Villa Grove Quadrangle ranges from very limited to more than adequate for domestic water supply needs and from none to moderate for municipal and industrial water supply requirements. For 50% to 70% of the quadrangle, successful well construction in the glacial drift for an adequate, year-round supply for domestic water needs is estimated as fair to good. This range is estimated to increase to 70% to 80% with the addition of all usable bedrock sources for water supply. Yields from glacial deposits in excess of 35 gpm on a sustained-pumping basis are estimated as available for less than 5% to 12% of the quadrangle.

The Devonian and Silurian bedrock in the western one-half and the northern one-third of the quadrangle offers fair to good potential for sustained yields of 25 to 75 gpm. Locally, yields of 300 to 600 gpm may be possible on an intermittent-pumping basis. High levels of mineralization preclude the use of all bedrock sources in the southeastern quarter of the quadrangle, except for limited supplies that may be available above a depth of about 200 feet.

REFERENCES

Illinois Environmental Protection Agency, 1997, Public Water Supply Division: Springfield, Illinois, Database.

Weibel, C.P., 1999, Topographic map of bedrock surface, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-BT, scale 1:24,000.

Weibel, C.P., and Z. Lasemi, 2001, Geological map of the bedrock surface, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-BG, scale 1:24,000.

Chapter 15

Aquifer Sensitivity

Richard C. Berg and Curtis C. Abert

The potential for aquifer contamination is a critical concern in Illinois and in the Villa Grove Quadrangle because chemical or biological agents from wastes introduced into aquifers pose potential health hazards. Residents of the Villa Grove Quadrangle are totally reliant on groundwater from aquifers as their drinking-water source.

Aquifer sensitivity is defined by the U.S. Environmental Protection Agency (1993) as the ease with which a contaminant applied on or near the surface can migrate to an aquifer. Aquifer sensitivity is a function of the characteristics of geologic materials and the overlying saturated and unsaturated materials; it is not dependent on land use or contaminant characteristics. Aquifers are vulnerable to contamination because their hydraulic properties allow dissolved wastes to travel rapidly within the aquifer.

AQUIFER SENSITIVITY MAPPING

For the *General Aquifer Sensitivity Map* (fig. 15-1), aquifers are defined as saturated, generally coarse-grained earth materials with a high saturated hydraulic conductivity that can provide at least enough water to small-diameter wells to support household needs. Aquifers in the glacial deposits in Illinois are generally composed of very well-sorted to moderately well-sorted sand and gravel deposits; in the bedrock, they are generally either porous sandstone or fractured limestone or dolomite (carbonate rocks) (Berg et al. 1984a, b). Silty and clayey river and lake sediment, diamicton (a mixture of gravel, sand, silt, and clay commonly called till), windblown silt (loess), shale, unfractured carbonates, and strongly cemented sandstones are not considered aquifers because they are fine grained and generally have low saturated hydraulic conductivity.

Important in mapping aquifer sensitivity is consideration of (1) near-surface sand and gravel aquifer materials above the water table and (2) subsurface non-aquifer materials with thin layers (<10 feet) of sand and gravel. The former materials are not saturated but still possess hydraulic properties conducive to rapid downward flow of potential contaminants to the saturated portion of the aquifer; therefore, they are mapped as part of the aquifer. The latter materials, although not widely used as aquifers, are mapped where they have an areal extent of at least 0.25 square mile and can potentially yield small amounts of water to residential wells.

The aquifer sensitivity analysis for the Villa Grove Quadrangle was based on rating successions of geologic materials

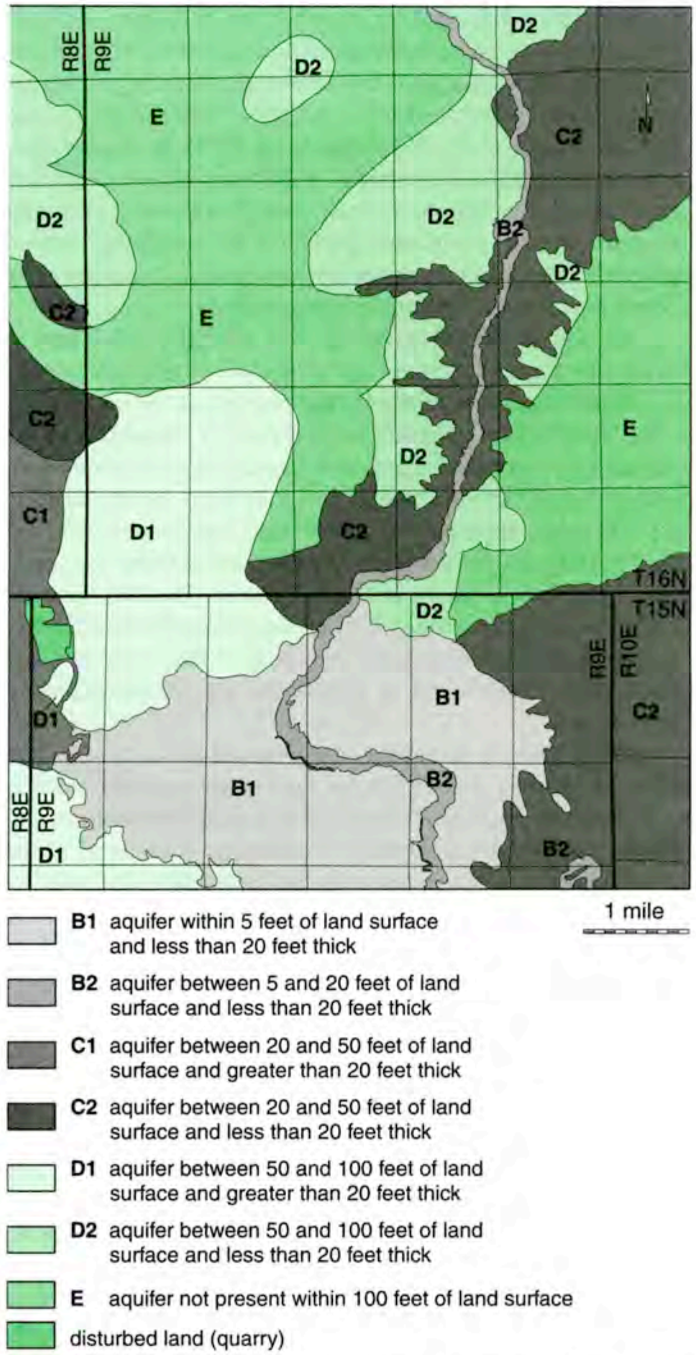


Figure 15-1 General Aquifer Sensitivity Map for the Villa Grove Quadrangle, Douglas County, Illinois.

to a depth of 100 feet according to their capacity to protect aquifers from potential contamination from septic system effluent, land burial of municipal wastes, surface applications of wastes (sewage sludge, manures, and road deicers) and chemicals

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

(agricultural and domestic chemicals and fertilizers), and accidental spills of wastes, chemicals, and other potentially harmful substances. Geologic materials were differentiated according to their thickness, texture, permeability, and stratigraphic position (where they lie in the vertical sequence).

The 100-foot depth limit for the mapping was chosen because groundwater quality investigations in Illinois and elsewhere in the glaciated midwestern United States suggest that contamination from agricultural chemicals markedly decreases in water samples collected below a depth of 100 feet (Klaseus et al. 1989, Schock et al. 1992, Libra et al. 1993). Because wastes travel through different materials at different rates, the sensitivity of aquifers within the various vertical sequences primarily depends on the protection provided by overlying layers. Materials that restrict the downward movement of contaminants reduce the potential for aquifer contamination.

The aquifer sensitivity ratings shown in figure 15-1 depend on the interpreted hydrogeologic properties of geologic materials. These properties include (1) the capacity of the materials to retain liquid wastes (or leachate) over time, (2) the ability of the materials to extract and retain polluting ions or compounds from a solution (attenuation characteristics), and (3) the rate that the geologic materials release non-attenuated ions, compounds, and complexes to the environment. We have not actually measured these properties, however, and emphasize that the categories are interpreted from the sequence of geological materials and other factors just discussed. The physical state of the potential waste product (solid, semi-solid, or liquid) also was not considered in the ratings.

Areas mapped as having low potential for contamination have the greatest probability for having geologically suitable sites for waste disposal. These are also areas where chemicals or wastes can be spilled, applied, or otherwise introduced to the environment without necessarily contaminating the groundwater. Thick deposits of fine-grained geologic materials serve as aquitards and offer the most protection to underlying aquifers. Conversely, areas mapped as having high potential for contamination occur where aquifers are close to the surface and are overlain by less than 50 feet of fine-grained deposits. These areas should be avoided for waste disposal or other potentially adverse land use activities.

The aquifer sensitivity ratings for the Villa Grove Quadrangle are based on the depth to the uppermost aquifer and its thickness, regardless of whether underlying aquifers are separated from the uppermost aquifer by fine-grained deposits. These criteria provide for the most conservative assessment.

The aquifer sensitivity map (fig. 15-1) cannot be used as a substitute for evaluation of individual sites. All areas where proposed or existing land use activities could adversely affect groundwater quality should be separately investigated because of variations in earth materials, the inherent limitations of the map scale, and the uneven distribution of the data used to produce geologic maps. Individual site evaluations should always consider the following factors (from Berg et al. 1984a,b; Curry et al. 1997) that cannot be evaluated at a regional scale:

1. the composition of the waste materials;
2. the volume and concentration of waste or chemical that is disposed, spilled, or applied (loading factors);
3. the distance of wells from contamination sites;
4. the number of nearby wells;
5. the depth to the seasonal water table;
6. minor slope variations;
7. the position of the waste site or application area with respect to groundwater recharge, discharge, and points between recharge and discharge areas;
8. areas at or near mapped material boundaries;
9. the density of disposal sites, septic systems, or application areas; and
10. the detailed geology of the site, especially the character of the sediments lying between the top of the uppermost aquifer and the potential contaminant(s).

Figure 15-1 was derived in part from the following maps developed for the Villa Grove mapping study: *Surficial Geology Map* (Hansel et al. 1999), *Geological Map of the Bedrock Surface* (Weibel and Lasemi 2001), and *Drift Thickness Map* (Weibel 1999). In addition, log descriptions of 124 water-well borings and 27 test and bridge borings provided the basis for delineating the thickness and distribution of subsurface diamictons and sand and gravel deposits. Figure 15-1 shows the basic depth-to-aquifer information, which is the basis for aquifer sensitivity maps for specific land uses (figs. 15-2, 15-3, 15-5, and 15-7). Colored larger scale versions of all figures are on the *General Aquifer Sensitivity Map* (Berg and Abert 1999).

MAP UNITS FOR THE AQUIFER SENSITIVITY ASSESSMENT

To maintain consistency with other maps of the potential for aquifer contamination in Illinois (e.g., Berg et al. 1984a, Berg 2001), Map Unit A is restricted to sand and gravel, high-permeability sandstone, or fractured and jointed carbonates exposed at the land surface. Because these do not occur in the Villa Grove Quadrangle, assessment begins with Map Unit B and progresses through Map Unit E according to decreasing sensitivity to contamination. The description of each unit (from Berg and Abert 1999) follows (for geologic descriptions of units see Hansel et al. 1999 and Chapter 11).

Map Unit B: Moderately High Potential for Aquifer Contamination

Map Unit B (fig. 15-1) delineates areas where surficial or near-surface sand and gravel deposits less than 20 feet thick are within 20 feet of the surface and are overlain by fine-grained deposits. Groundwater within these thin sand and gravel deposits is not commonly used. There is, however, a potential for contaminants to migrate within these sand and gravel layers and eventually discharge along slopes or into surface-water bodies, especially along the contact with any underlying fine-grained deposits.

Map Unit B1 Areas described as B1 are where surficial sand and gravel deposits less than 20 feet thick occur within 5 feet of the land surface and overlie fine-grained silty lakebed deposits (Equality Formation) or silty diamicton (Batestown Member of the Lemont Formation). A large B1 area occurs in the south-central portion of the quadrangle where there are sandy delta deposits (Henry Formation).

Map Unit B2 In B2, sand and gravel deposits less than 20 feet thick are overlain by 5 to 20 feet of fine-grained deposits. This situation occurs along the floodplain of the Embarras River where thin sand and gravel (Henry Formation) is overlain by silty alluvium (Cahokia Formation) and underlain by silty diamicton or lakebed deposits.

Map Unit C: Moderate Potential for Aquifer Contamination

A moderate potential for contamination exists in areas where sand and gravel or fractured and jointed carbonates are buried by 20 to 50 feet of fine-grained deposits. Twenty to fifty feet of fine-grained material offers moderate protection for underlying aquifers from waste-spreading or densely spaced septic systems. For example, Schock et al. (1992) reported that, in Illinois, the occurrences of pesticide or nitrate detections were significantly fewer where the aquifer was buried 20 to 50 feet than where aquifers were shallower.

Map Unit C1 Areas designated C1 are where sand and gravel deposits are 20 feet thick or greater or more or where fractured and jointed carbonates are overlain by 20 to 50 feet of fine-grained deposits. This succession is prevalent along the west-central border of the quadrangle.

Map Unit C2 In C2 areas, sand and gravel deposits less than 20 feet thick are overlain by 20 to 50 feet of fine-grained deposits. The most extensive areas with this succession occur in the southeastern portion of the quadrangle and along the Embarras River from Patterson Springs to Villa Grove.

Map Unit D: Moderately Low Potential for Aquifer Contamination

A moderately low potential for contamination exists in areas where sand and gravel or fractured and jointed carbonates are buried beneath 50 to 100 feet of fine-grained deposits. Schock et al. (1992) further reported that, in Illinois study areas, occurrences of pesticide or nitrate detections were significantly fewer where the aquifer was buried deeper than 50 feet than where aquifers were buried 20 to 50 feet.

Map Unit D1 Areas in map Unit D1 are where sand and gravel deposits are 20 feet thick or greater or where fractured and jointed carbonates are overlain by 50 to 100 feet of fine-grained deposits. These map areas exist in the southwestern and west-central portions of the quadrangle.

Map Unit D2 These D2 areas are where sand and gravel deposits less than 20 feet thick are overlain by 50 to 100 feet of fine-grained deposits. Extensive D2 areas occur around Camargo and in upland settings adjacent to the C2 map areas along the Embarras River from Camargo to Villa Grove.

Map Unit E: Low Potential for Aquifer Contamination

A low potential for contamination exists in areas underlain by at least 100 feet of fine-grained deposits. Map Unit E areas are among the areas least sensitive to groundwater contamination because of the absence of aquifers and the presence of thick, fine-grained deposits. Some areas are underlain by non-aquifer Pennsylvanian rocks at depths of less than 100 feet. Extensive E areas occur in the east-central and northwestern areas of the quadrangle.

Although the contamination potential of aquifers decreases as the thickness of overlying fine-grained materials increases, historic water-quality analyses of samples throughout Illinois indicate that shallow groundwater (but not in aquifers) in the fine-grained materials may be contaminated (Schock et al. 1992). This shallow groundwater contamination means that land use practices such as farming, landfilling of wastes, and septic fields can apparently result in contaminants moving rapidly through fractures in the fine-grained materials and causing unexpected contamination of shallow groundwater in large-diameter wells.

AQUIFER SENSITIVITY TO MUNICIPAL AND HAZARDOUS WASTE DISPOSAL

Perhaps the land use with the greatest potential for aquifer contamination is municipal and hazardous waste disposal sites. Figure 15-2 can be used to make a preliminary assessment of existing sites and, more importantly, to screen the quadrangle for regions where the probability of finding suitable sites is greatest.

Map Units B and C: High Potential for Aquifer Contamination from Waste Disposal Facilities

Regions designated as B and C in figure 15-1 all contain sand and gravel aquifers or fractured and jointed carbonates within 50 feet of the land surface and are extremely sensitive (see “high” designation on fig. 15-2) to potential contamination from waste disposal facilities. Waste buried in a pit or trench up to 50 feet deep may be placed in direct contact with aquifer materials; therefore, there is little or no natural protection of an aquifer by overlying finer-grained materials.

In B1 areas, where thin sand and gravel is underlain by thick diamicton, it may be possible to remove the sand and gravel to the top of the fine-grained deposit. However, waste and effluent could still be in contact with sand and gravel at the sides of a landfill trench.

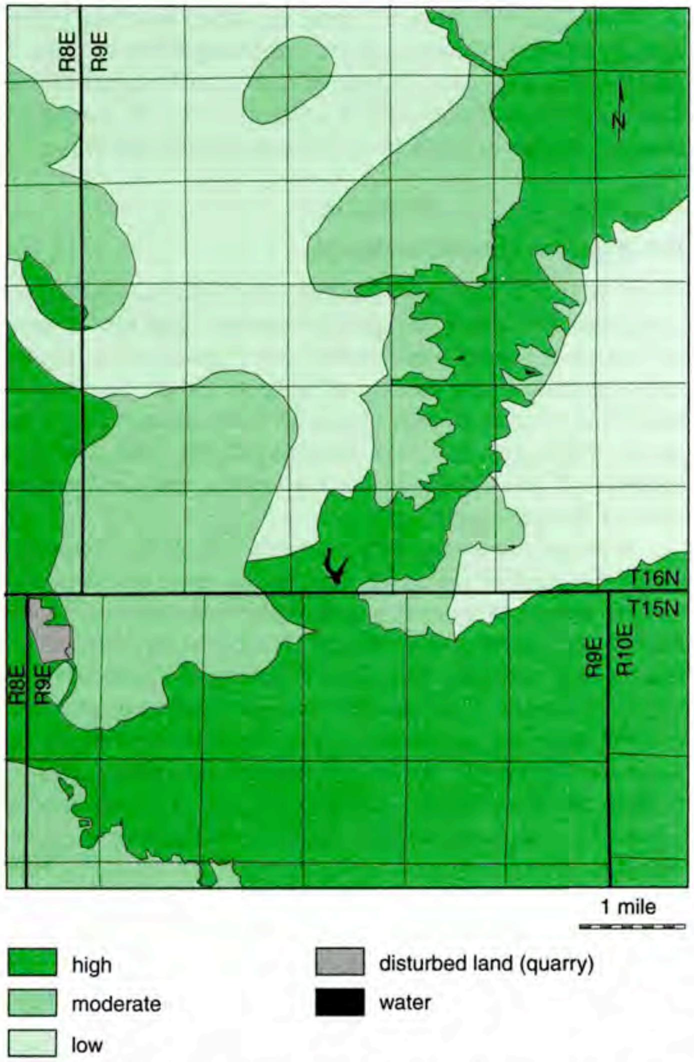


Figure 15-2 Aquifer sensitivity to municipal or hazardous waste disposal in the Villa Grove Quadrangle.

Map Unit D: Moderate Potential for Aquifer Contamination from Waste Disposal Facilities

Map Unit D includes areas where sand and gravel deposits or fractured and jointed carbonates are present but are overlain by 50 to 100 feet of fine-grained deposits. These areas are designated "moderate" on figure 15-2. Although the aquifer sensitivity rating is relatively low because fine-grained materials separate the aquifer from the land surface, aquifers can occur within 50 feet of the land surface. Berg (1994) and Curry et al. (1997) state that municipal waste disposal may be acceptable if the aquifer is closer to the 100-foot depth maximum. At least 50 feet of undisturbed fine-grained materials should remain between the bottom of a landfill trench and the aquifer.

In D areas, if a landfill trench 100 feet deep is proposed, then the potential for contamination of an underlying aquifer would be high, not moderate. Areas mapped as D should not be used for hazardous waste disposal. Another problem is that significant parts of D areas have poor surface drainage conditions and a seasonally high water table. Although thick, fine-grained deposits reduce the potential for aquifer contamination, the potential exists for surface-water contamination through runoff of contaminated water. Landfills also may be troublesome to design, engineer, and operate in poorly drained areas. Nonshaded areas of figure 15-3 show where poor soil drainage may cause problems for developing a waste disposal facility.

Map Unit E: Low Potential for Aquifer Contamination from Waste Disposal Facilities

Unit E exists where there are at least 100 feet of surficial, fine-grained deposits or where the Pennsylvanian bedrock (a non-aquifer) occurs within 100 of the land surface and is overlain by fine-grained deposits. Such areas have a low potential (fig. 15-2) for contamination from municipal or, perhaps, hazardous wastes because of a lack of aquifers in the uppermost 100 feet. However, it is usually politically and, sometimes, environmentally wise to avoid locating any waste disposal facility over aquifer materials at any depth. Waste disposal facilities must always be designed, constructed, and carefully monitored to minimize their potential for aquifer contamination. As with D areas, poor drainage conditions are common in E areas, and contaminants could travel to surface-water bodies through surface flow. Detailed site-specific investigations must be conducted to verify the absence of aquifer materials in these areas.

In the southwestern part of the quadrangle is an area of disturbed land, shown on figure 15-2, where bedrock is exposed at a quarry. The aquifer material that is being quarried is porous and highly permeable Devonian and Silurian dolomites about 160 feet below the land surface but exposed at the bottom of the quarry. This situation, however, poses little threat as a contamination source as long as normal quarry operations are in place and land use at the quarry does not change. For example, a contamination hazard could be created if the quarry were used for waste disposal or if a major chemical spill occurred in or near the quarry.

AQUIFER SENSITIVITY TO SEPTIC SYSTEMS

The principal consideration in rating land areas for their suitability for septic systems is the permeability of the geologic materials and their capacity to protect aquifers from contamination. Also important is the number of septic systems operating within a specified area: sensitive geologic settings must not be overloaded with septic effluent. The most common wastes in septic effluent include bacteria, nitrates, and solvents (e.g., from household cleaners).

Materials with high hydraulic conductivities (such as sand and gravel) will readily accept septic effluent, but they produce a contamination hazard if effluent escapes faster than natural decomposition and attenuation can occur. Conversely, the potential for aquifer contamination is low in materials (such as diamicton) having low hydraulic conductivities, but the

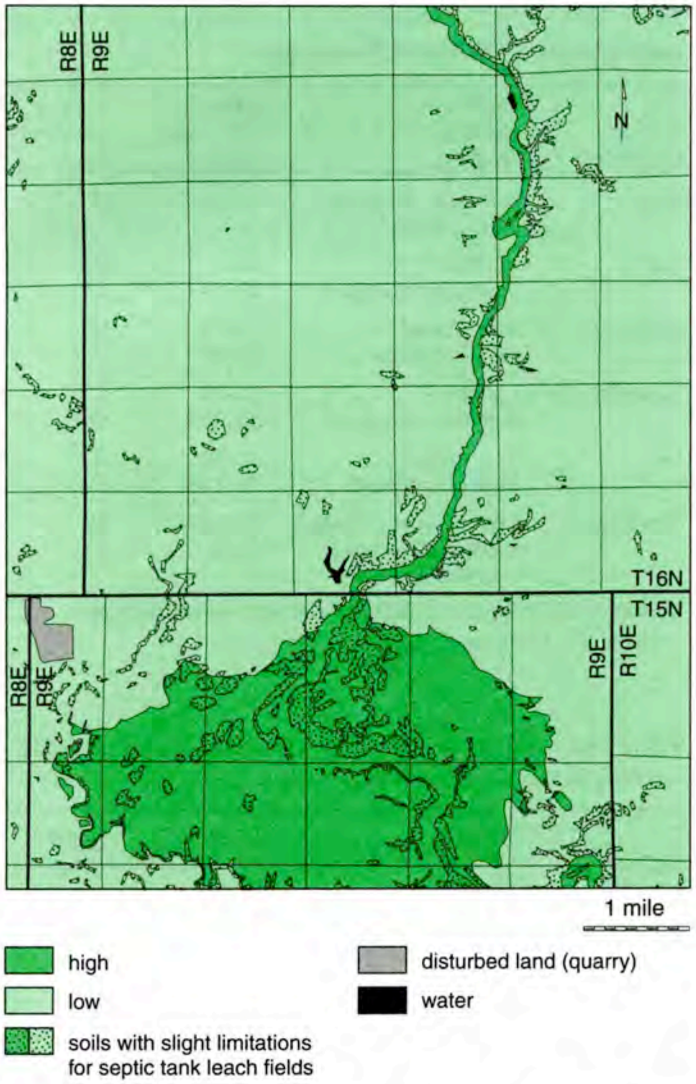


Figure 15-3 Aquifer sensitivity to septic leachate in the Villa Grove Quadrangle.

septic systems may not operate properly because of poor soil drainage conditions.

Variation in soil drainage is a primary factor that affects planning and development decisions, particularly those involving suitability of land areas for septic systems. Soil drainage also affects waste-disposal considerations and light construction operations. Soil drainage is directly dependent upon (1) local and regional topography; (2) the depth (and fluctuations in depth) to the top of the water table; (3) the hydraulic conductivity of soils and the underlying geologic parent materials; (4) local and regional groundwater flow systems; and (5) the location of surface-water bodies and drainageways (Berg et al. 1984a). Poor soil drainage conditions prevail over about 95% of the Villa Grove Quadrangle (Hallbick and Fehrenbacher 1971).

Soil maps show the distribution of soil series, which are defined, in part, by the composition and origin of the soil's parent material and by the soil drainage class; both affect the ease with which water moves through the soils and the depth to the seasonal water table. The non-stippled regions of figure 15-3 show soils that were classified by Hallbick and Fehrenbacher (1971) as having "moderate" and "severe" limitations for septic tank disposal fields. Under natural conditions, these areas are subject to flooding, seasonally high water tables, or local ponding; they also are areas where wet basements are more likely to occur. Most of the soils have limitations caused by "very poor," "poor," "somewhat poor," and "moderately good" soil drainage. Other soils have severe limitations because of steep slopes, difficulties of septic tank installation, and the potential for effluent to seep to the surface and contaminate surface-water supplies. Stippled regions on figure 15-3 indicate soils that pose "slight" limitations for septic tank disposal fields. These areas are characterized by well-drained soils that can rapidly transmit water through soil profiles and potentially contaminate underlying groundwater resources. Areas with slight limitations for septic systems primarily occur adjacent to the Embarras River and some of its small tributaries, as well as in the south-central portion of the quadrangle where well-drained sand and gravel was deposited in a delta in glacial Lake Douglas.

Map Unit B: High Potential for Aquifer Contamination

Regions designated as B on figure 15-1 are extremely sensitive (see "high" designation on fig. 15-3) to potential contamination from septic system effluent, particularly where a sand and gravel aquifer lies within 5 feet of the surface (Map Unit B1). Sand and gravel aquifers in B areas have a low potential for transmitting contaminants to underlying aquifers, but contaminants are more likely to reach lakes, rivers, and streams because of the tendency of contaminants to migrate along the underlying contact with materials of lower hydraulic conductivity. (Low hydraulic conductivity materials are finer grained; therefore, a contaminant is more likely to flow on its surface rather than infiltrate it.)

Map Units C, D, and E: Low Potential for Aquifer Contamination

A low potential for contamination (fig. 15-3) from septic systems occurs in areas where fine-grained deposits are thicker than 20 feet. The fine-grained sediments provide protection to the aquifer from septic effluent. The 50 to more than 100 feet of fine-grained sediments in D and E areas provide considerable protection to the aquifer. Although the groundwater contamination hazard is minimal in C, D, and E areas, infiltration of septic effluent into the geologic materials may be a problem and could contribute to groundwater contamination in areas where wells have been improperly constructed (these conditions may also occur locally in B areas).

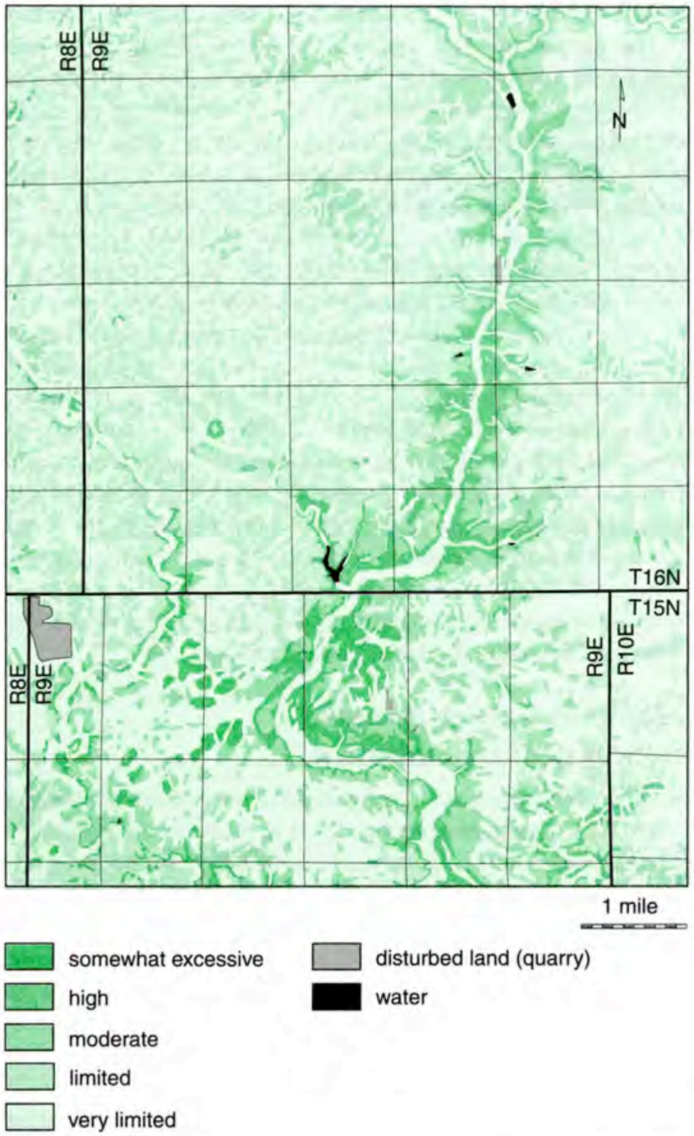


Figure 15-4 Soil nitrate leaching classes in the Villa Grove Quadrangle.

Table 15-1 Aquifer sensitivity to contamination by nitrate leaching in the Villa Grove Quadrangle.

Aquifer sensitivity	Pesticide leaching class	Depth to upper aquifer (feet)	General sensitivity class
Very high	Somewhat excessive to moderate[1]	<20	B
High	Limited	<20	B
	Somewhat excessive	20–50	C
Moderate	Very limited	<20	B
	High or moderate	20–50	C
Somewhat low	Limited	20–50	C
	Somewhat excessive	50–100	D
Low	Very limited	20–50	C
	High or moderate	50–100	D
Very Low	Limited or very limited	50–100	D
	Somewhat excessive to very limited[2]	>100	E

[1]Includes somewhat excessive, high, and moderate soil leaching classes.
[2]Includes all nitrate leaching classes.

Table 15-2 Aquifer sensitivity to contamination by pesticide leaching in the Villa Grove Quadrangle.

Aquifer sensitivity	Pesticide leaching class	Depth to upper aquifer (feet)	General sensitivity class
Very high	High or moderate	<20	B
High	Somewhat limited	<20	B
Moderate	Very limited	<20	B
	High or moderate	20–50	C
Somewhat low	Somewhat limited to very limited[1]	20–50	C
Low	High	50–100	D
Very low	Moderate to very limited[2]	50–100	D
	High to very limited[3]	>100	E

[1]Includes somewhat limited, limited, and very limited soil leaching classes.
[2]Includes moderate, somewhat limited, limited, and very limited leaching classes.
[3]Includes all pesticide leaching classes.

AQUIFER SENSITIVITY TO AGRICULTURAL CHEMICALS AND OTHER SURFACE ACTIVITIES

The potential for groundwater contamination from land surface activities—such as application of agricultural chemicals, surface-spreading of wastes (e.g., sewage sludge, manure, and septage), and accidental chemical spills—is similar to the potential for contamination from septic systems. However, more waste reduction is likely to occur from land surface activities than from septic systems because of the likely attenuation of contaminants in the soil profile. Application rates for surface-spreading of wastes and for agricultural chemicals are dependent on the slope, soil type, soil characteristics, and amount of precipitation.

Because more than 95% of the land area of the Villa Grove Quadrangle is agricultural, a comprehensive aquifer sensitivity assessment must include an examination of the potential for infiltration of nitrates (from fertilizers) and pesticides through surface soils and the potential for attenuation of pesticides by soil organic matter (Keefer 1995). Keefer (1995) conducted an extensive statewide analysis of how differences in soil associations (soil associations are generalizations of soil series, the basic soil map unit used on county soil maps) and aquifer depths affected the potential for aquifer contamination by agricultural chemicals. Although Keefer's study used only soil associations, he also designated nitrate and pesticide leaching classes for individual soil series in Illinois. These soil series designations were used to assess aquifer sensitivity from agricultural chemicals for the Villa Grove Quadrangle. The boundaries of

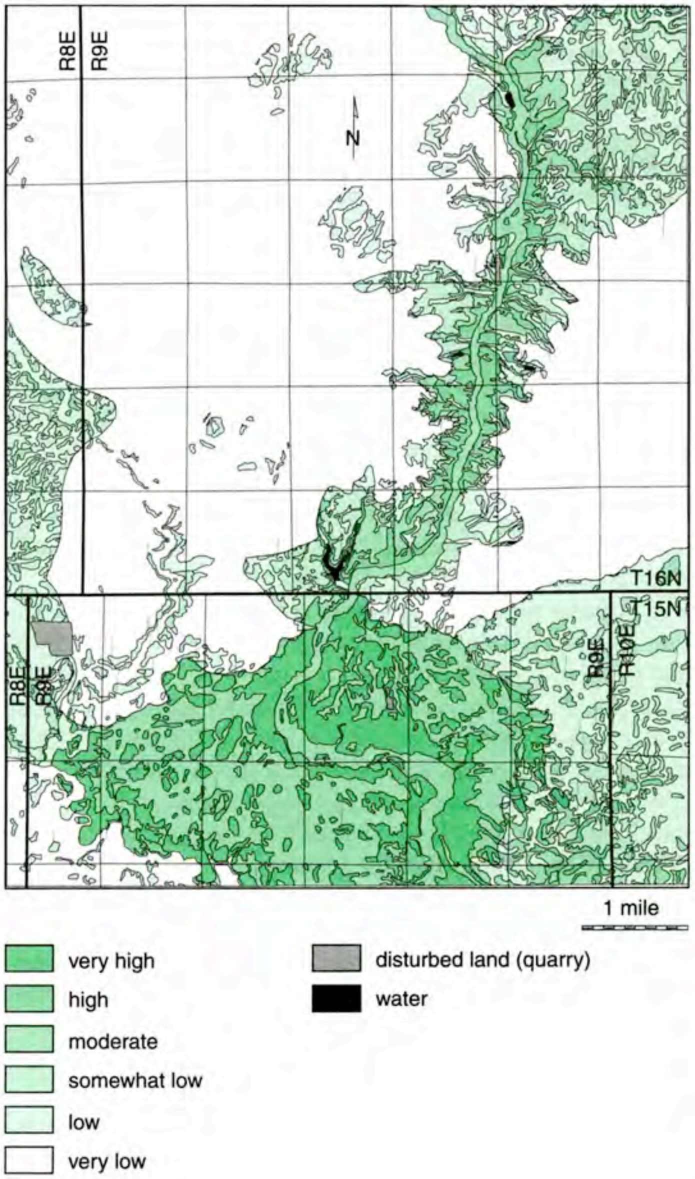


Figure 15-5 Aquifer sensitivity to nitrate leaching in the Villa Grove Quadrangle.

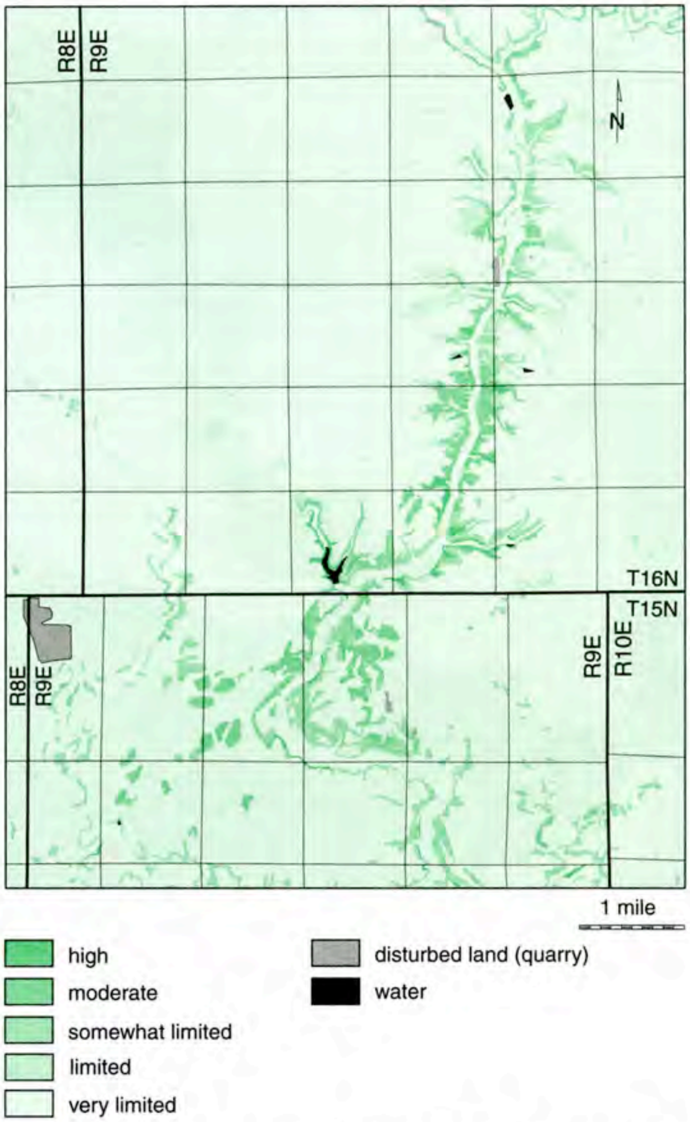


Figure 15-6 Soil pesticide leaching classes in the Villa Grove Quadrangle.

the soil series for the quadrangle were converted from the *Soil Survey of Douglas County, Illinois* (Hallbick and Fehrenbacher 1971) into an electronic database. Keefer's methods were then used to combine nitrate and pesticide leaching classes of the soil series with depth to the uppermost aquifer to assess aquifer sensitivity from agricultural chemicals on the quadrangle.

Potential for Nitrate Contamination of Aquifers

Nitrate leaching classes As mentioned by Keefer (1995), the development of a map showing the nitrate leaching characteristics of soils must consider soil properties relating to the water movement characteristics of the soil and the likelihood of water movement below the root zone and potentially to an underlying aquifer. Therefore, the two most significant factors are the hydraulic conductivity (ease of water movement through a soil profile) and drainage class of the soils. Keefer calculated the rate of water movement through the soil by dividing the thickness of each soil profile horizon by the hydraulic conductivity of that horizon. The horizon values were summed to provide a travel time index.

Drainage classes provide a rough measure of the depth to the seasonally high water table in a soil profile. Soils in areas where the water table remains near the surface for extended periods experience restricted through-flow of water. Soils with deep water tables do not restrict the flow of water as much. Therefore, soils with seasonally deep water tables are more likely to allow nitrate to leach through the soil profile than are soils with seasonally shallow water tables. Keefer (1995) developed a nitrate leaching classification for each soil series in Illinois, including those soils on the Villa Grove Quadrangle, by combining the travel time index and drainage class. The Villa Grove

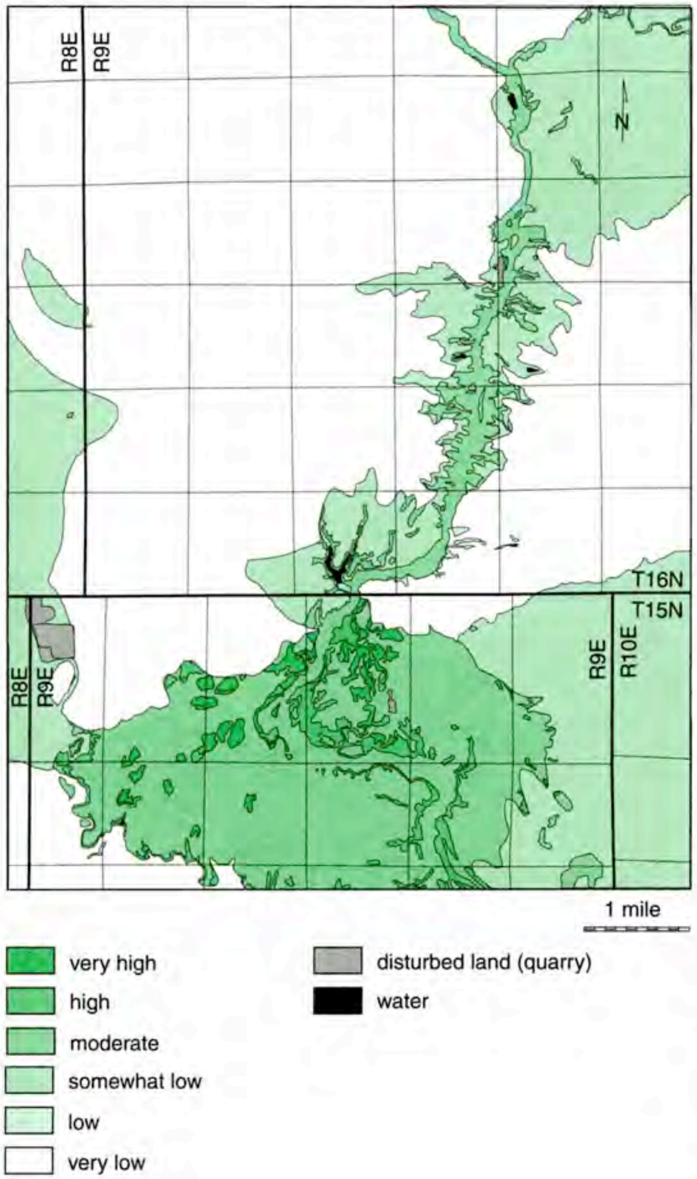


Figure 15-7 Aquifer sensitivity to pesticide leaching in the Villa Grove Quadrangle.

Quadrangle soils are grouped into five nitrate leaching classes according to the relative probability for nitrate moving through their profiles (fig. 15-4).

Aquifer sensitivity to contamination by nitrate leaching The nitrate leaching data (fig. 15-4) were combined with the depth to aquifer data (fig. 15-1; table 15-1). The resulting map (fig. 15-5) identifies areas having aquifer settings with similar water and transport characteristics according to sensitivity. The highest sensitivity areas generally are in the south-central portion of the quadrangle and along the Embarras River. In addition to evaluating aquifer sensitivity to nitrate contamination from fertilizers, the map can also be used to evaluate sensitivity to nitrates from surface application of sewage sludge and septage, from large animal confinement facilities, and from salts used as road deicers.

Potential for Pesticide Contamination of Aquifers

Pesticide leaching classes The ability of a pesticide to move through the soil profile is greatly affected by the pesticide's tendency to adsorb to soil organic matter or clay particles; such adsorption retards pesticide movement relative to water movement through the soil (Keefer 1995). Organic matter is more likely to adsorb pesticides than are clay particles. (Nitrates, however, are minimally affected by either organic matter or clays and readily move into soil water and groundwater.) Organic matter classes were calculated for all soil series in Illinois by Keefer (1995), including those of the Villa Grove Quadrangle, by multiplying the thickness of the surficial horizon by the percentage of organic matter to derive a surficial organic matter index. The soil series on the Villa Grove Quadrangle are grouped into pesticide leaching classes on the basis of the relative probability of pesticide movement through their profiles (fig. 15-6)

Aquifer sensitivity to contamination by pesticide leaching The pesticide leaching data (fig. 15-6) were combined with the depth to aquifer data (fig. 15-1; table 15-2). The resulting map (fig. 15-7) shows areas having aquifer settings of similar water and transport characteristics according to sensitivity. As on the nitrate sensitivity map (fig. 15-5), the highest sensitivities occur primarily in the south-central portion of the quadrangle and along the Embarras River. Aquifer sensitivity is lower for pesticides than for nitrates because the amount of organic matter is not a factor in determining aquifer sensitivity to nitrates. In addition to use in evaluating aquifer sensitivity to contamination by pesticides (both from agricultural and residential use), the map can also be used to evaluate sensitivity to other organic chemicals.

CONCLUSIONS

Aquifer sensitivity assessment is a principal product of the Illinois State Geological Survey's 1:24,000-scale geologic quadrangle mapping program. Understanding the lateral extent, thickness, and depth to aquifers is critical information for land use planners, health officials, developers, managers of industrial and commercial enterprises, and private citizens who need to evaluate areas for potential contamination problems, to direct potentially adverse land use practices to areas where groundwater contamination potential is low, and to help evaluate where shallow groundwater resources might be a potential drinking-water source. Specifically, this assessment can provide planners with scientifically based information to make wise and effective development decisions in response to demands for "smart growth."

REFERENCES

Berg, R.C., 1994, Geologic aspects of a groundwater protection needs assessment for Woodstock, Illinois—A case study: Illinois State Geological Survey, Environmental Geology 146, 27 p.

Berg, R.C., 2001, Aquifer sensitivity classification for Illinois using depth to uppermost aquifer material and aquifer thickness: Illinois State Geological Survey, Circular 560, 14 p.

Berg, R.C., and C.C. Abert, 1999, General aquifer sensitivity map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-AS, scale 1:24,000.

Berg, R.C., J.P. Kempton, and K. Cartwright, 1984a, Potential for contamination of shallow aquifers in Illinois: Illinois State Geological Survey, Circular 532, 30 p.

Berg, R.C., J.P. Kempton, and A.N. Stecyk, 1984b, Geology for planning in Boone and Winnebago Counties: Illinois State Geological Survey, Circular 531, 69 p.

Curry, B.B., R.C. Berg, and R.C. Vaiden, 1997, Geologic mapping for environmental planning, McHenry County, Illinois: Illinois State Geological Survey, Circular 559, 79 p.

Hallbick, D.C., and J.B. Fehrenbacher, 1971, Soil survey of Douglas County, Illinois: Champaign, Illinois, U.S. Department of Agriculture, Soil Conservation Service, in cooperation with Illinois Agricultural Experiment Station, 81 p.

Hansel, A.K., R.C. Berg, and C.C. Abert, 1999, Surficial geology map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-SG, scale 1:24,000.

Keefer, D.A., 1995, Potential for agricultural chemical contamination of aquifers in Illinois: Illinois State Geological Survey, Environmental Geology 148, 28 p.

Klaseus, T.G., G.C. Buzicky, and E.C. Schneider, 1989, Pesticides and groundwater—Surveys of selected Minnesota wells: Minneapolis, Minnesota, Minnesota Department of Public Health and Minnesota Department of Agriculture, 95 p.

Libra, R.D., G.R. Hallberg, K.D. Rex, B.C. Kross, L.S. Seigley, M.A. Kulp, R.W. Field, D.J Quade, M. Selim, B.K Nations, N.H. Hall, L.A. Etre, J.K. Johnson, H.F. Nicholson, S.L. Berberich, and K.L. Cherryholmes, 1993, The Iowa state-wide rural well-water survey—June 1991, Repeat sampling of the 10% subset: Des Moines, Iowa, Iowa Department of Natural Resources Technical Information Series 26, 30 p.

Schock, S.C., E. Mehnert, M.E. Caughey, G.B. Dreher, W.S. Dey, S. Wilson, C.Ray, S.F.J. Chou, J. Valkenburg, J.M. Gosar, J.R Karny, M.L Barnhardt, W.F. Black, M.R. Brown, and V.J. Garcia, 1992, Pilot study—Agricultural chemicals in rural, private wells in Illinois: Illinois State Geological Survey, Illinois State Water Survey, and Illinois Department of Agriculture, Cooperative Groundwater Report 14, 80 p.

U.S. Environmental Protection Agency, 1993, Ground water resource assessment: Washington, D.C., Office of Water 4602, EPA 813-R-93-003, 232 p.

Weibel, C.P., 1999, Drift thickness map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-DT, scale 1:24,000.

Weibel, C.P., and Z. Lasemi, 2001, Geological map of the bedrock surface, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ Villa Grove-BG, scale 1:24,000.

Chapter 16

Engineering Geology, Natural Hazards, and Construction Materials

Christopher J. Stohr

The Villa Grove Quadrangle is subject to many natural hazards, including flooding, poorly drained lacustrine deposits, and unstable slopes. Some areas have high susceptibility to frost heaving and soil shrinking and swelling. Because few ideal building sites exist, remedial work or special design techniques may be necessary for some types of construction. The ideal site for most structures (1) has no known natural hazards, (2) has thick, well-drained soil materials having a high bearing capacity, and (3) can be excavated with minimum difficulty. These conditions, however, are not found in this quadrangle.

The *Construction Conditions, Natural Hazards Map of the Villa Grove Quadrangle, Douglas County, Illinois* (Stohr 2001) was prepared to show the occurrence of natural hazards and the suitability of materials to support light construction (generally involving one- and two-story buildings with shallow foundations and relatively low loads transmitted to footings). Because soil type can significantly influence geologic conditions at a specific site, detailed information on soils available from the *Soil Survey of Douglas County, Illinois* (Hallbick and Fehrenbacher 1971) and the *General Aquifer Sensitivity Map* (Berg and Abert 1999) should be used along with data from this report.

NATURAL HAZARDS

Flooding

Flooding of the Embarras River has been a recurring problem for the Village of Villa Grove and vicinity (Federal Emergency Managment Agency 1985). The Drummer and Flanagan soils that dominate this area have a high capacity to hold water and generally require tilling to improve drainage for row crops. Consequently, soils can store only a small amount of water following a rainstorm; coupled with moderate permeability, this soil condition causes runoff to drain slowly to the low gradient of the Embarras River. Although the greatest hazard tends to be seasonal, the likelihood of flooding and flash flooding is prevalent throughout the year. For further information, contact the Illinois State Water Survey, 2204 Griffith Drive, Champaign, Illinois 61820.

Slope Unstability

Unstable slopes occur at cutbanks (steep or overhanging slopes) recently eroded along the outsides of meanders of the Embarras River and tributaries. Slope instability may also occur along deep excavations for quarrying rock. Colluvium mapped along the Embarras River, Scattering Fork, and Hackett Branch delineates slopewash and ancient landslides where cutbanks have collapsed as material is eroded from the toe of the slope. Stream banks are also susceptible to erosion, numerous examples of which can be found along banks of rivers and streams.

Lacustrine Silts and Clays

Lacustrine silts and clays occur in the quadrangle south of U.S. Route 36, especially in the floodplain of the Embarras River and behind the Arcola Moraine. These materials can cause significant construction problems because variations in types of expandable clay minerals and soil drainage allow differential settlement of soils to occur in structures founded on these materials. Excavations in lacustrine deposits fill with water because of the poor drainage, low relief, and high water table; therefore, a basement foundation may exhibit buoyancy if groundwater is not drained or pumped to lower the water table. Basement construction is not desirable in such a setting unless special building techniques are used. Landscape position is very important in siting small structures on lacustrine materials; slightly elevated sites are desirable. The *Soil Survey of Douglas County, Illinois* map (Hallbick and Fehrenbacher 1971), used in conjunction with the *Construction Conditions, Natural Hazards* (Stohr 2001), should be helpful for locating suitable construction sites in lacustrine materials.

Soil Shrinkage and Swelling

Building foundations, driveways, and roads can be damaged by shrinkage and swelling of soils. Heaving of the ground surface can result from expansion caused by water absorption. Settlement can occur from soil dessication through plant transpiration or by evaporation. The *Soil Survey of Douglas County, Illinois* map (Hallbick and Fehrenbacher 1971) shows that upland surface soils have moderate shrink-swell susceptibility, whereas areas near major drainages tend to have low susceptibility. Soils derived from loess and lacustrine silts are most susceptible to the shrinking and swelling resulting from changes in water content. It is not known whether tills have this characteristic, but till is not thought to be susceptible to this phenomenon. Outwash composed of sand and gravel in the south-central area generally does not shrink and swell.

Frost Heaving Susceptibility

Susceptibility to frost heaving is the potential for upward or lateral movement of soil caused by freezing of water in soil

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

pores. Building foundations, driveways, and roads may suffer seasonal damage. On the basis of measurements taken at sod-covered ground during 1980–1996, the earliest ground frost is on December 10, and the latest ground frost is on March 15. For 1981–1982, the ninth coldest winter of record and the coldest during the 1980–1996 interval, the deepest frost penetration was 25 cm (10 inches), and mean frost penetration was about 10 cm (4 inches) (Wendland 1998).

Drainage Conditions

Most of the quadrangle's soils are somewhat poor to poorly drained; a seasonally high water table poses a challenge for dry basement construction. Improved drainage conditions are found adjacent to major streams and gullies.

The gentle slope of the sandy deltaic deposits might pose problems in the excavation and construction of structures. The slope of the buried deltaic sediments (Fraser and Steinmetz 1971) can allow water to drain by gravity into a downslope excavation. Furthermore, an excavated basement can act as a subsurface impoundment (obstacle) to flow, subjecting the structure to hydraulic pressures, leakage, and possibly piping. Shallow groundwater head and volume of subsurface flow should be considered in the design of structures in deltaic sediments shown on the *Surficial Geology Map* (Hansel et al. 1999) and the *Construction Conditions, Natural Hazards Map* (Stohr 2001) of the quadrangle.

Amplification of Earthquake-induced Vibrations

The amount of amplification of earthquake-induced vibrations has not been measured directly. The nearest epicenter having a Richter magnitude greater than or equal to 5 was the 5.1 magnitude earthquake that occurred at Lawrenceville, Illinois, in June 1987. Although the quadrangle lies close to the Wabash Valley Fault Zone and the New Madrid Seismic Zone (Heigold and Larson 1990), earthquake vibrations from those seismic areas are not likely to severely affect most well-built and well-maintained buildings. Poorly maintained chimneys, unreinforced masonry, unsecured interior objects, and sensitive electronic components of computers and instruments would be most affected. Vibrations would probably be amplified in alluvial and saturated materials. Although the design of critical facilities should account for earthquake vibrations, structures on upland diamicton areas are less likely to be affected.

MATERIAL PROPERTIES AND EASE OF EXCAVATION

The properties of earth materials depend on many factors, including loading history, material types, particle size distribution, drainage characteristics, and moisture content. Table 16-1 presents standard penetration, pocket penetrometer, unconfined uniaxial compression, compaction, and hydraulic conductivity values obtained from several borings and bearing capacity tests.

Although partly dependent on weather and human factors (operator efficiency and machinery used), ease of excavation is related primarily to the geologic materials being excavated and the site's position on the landscape. Loess, which composes the initial 3.5 feet of surface material, is easiest to excavate, although wet conditions and a high water table in spring impede digging. Till is more difficult to excavate because of its greater density and cohesion. Unweathered diamicton (till) has near-optimum natural moisture content for compaction, but it can require tilling to break up large pieces for compaction. Particle size distribution by mechanical analysis and hydrometer is given in table 16-2.

Lacustrine Silts and Clays

Lacustrine silts and clays are composed of laminated silt, clay, and fine sand, which commonly are poorly drained and (when exposed at the surface) subject to flooding or long-standing water. Abundance of expandable clay minerals contributes to adverse shrink-swell and frost susceptibility. Excavation is hampered by poor drainage and a high water table. Conservative design practice may preclude building in the area or require special engineering.

Diamicton (Till)

Diamicton (till) is composed of well-graded (poorly sorted) silt, sand, and clay with some gravel. Sand layers and lenses are common inclusions in diamicton. Diamicton is suitable for most construction fill materials and as a foundation for small structures. This dense till is usually excavated with moderate difficulty, and it provides adequate foundation support for most light construction. Till has low primary permeability through the matrix but allows low to moderate secondary permeability through joints and fractures. Consequently, the loess-till interface tends to restrict vertical drainage, and a water table often develops at that surface. Moraine (end moraine) areas tend to be more heterogeneous than the till plain (diamicton) and have different soil conditions and materials in their distal and proximal slopes.

Sand and Gravel

Sand and gravel can be found in limited quantities along the Embarras River. At the south end of the quadrangle, up to 10 feet of sand is found in deltaic deposits beneath 3 feet of silt. Isopleths show the thickness of the sand, which is composed of progressively smaller proportion of fines with depth (Fraser and Steinmetz 1971, Hansel et al. 1999).

Limestone/Dolomite

Limestone/dolomite can be obtained from the Tuscola Stone Company quarry east of Tuscola on U.S. Route 36. Crushed dolomite is available for concrete and bituminous aggregate and roadbed materials.

Table 16-1 Material properties[1] of typical soils in the Villa Grove Quadrangle.

Soil	Classification		Atterberg Limits				Strength			Compaction		Remolded hydraulic conductivity (cm/sec)
	USCS[2]	AASHTO	W	PL	LL	PI	N	Qu (t/ft^2)	P (t/ft^2)	Max. dry density (lb/ft)	Optimum moisture content (%)	
Peoria Silt	CL	A-6 (11)		19	38	19						
Peoria Silt	CL	A-6 (4)		15	27	12						
Peoria Silt	CL	A-7,6 (15)		24	42	18				103	19	
Diamicton Brown sandy clay Batestown Member	CL	A-6 (8)	18	18	32	14	31	8.73	4.5+	124.4	12.3	0.11×10^{-7}
Diamicton Brown silty clay Batestown Member	CL	A-6 (12)	24	21	43	22	12	3.30	3.8	121.2	11.4	7.7×10^{-7}
Diamicton Gray silty clay Batestown Member	CL	A-6 (10)	13	16	29	13	13	2.33	2.3	134.1	8.5	4.5×10^{-7}
Diamicton Gray silty clay + coarse sand Batestown Member	CL-ML	A-4 (0)	13	15	19	4	31	12.02	4.5+	125.8	10.7	

[1]Source: Composited geotechnical engineering laboratory testing data are provided courtesy of S. Robinson, Illinois Department of Transportation District 5, Paris, Illinois; D. Hambly and J. Nelson, Graef, Anhalt, Schloemer, Chicago, Illinois; and D. Kerns, Hanson Engineers, Incorporated, Springfield, Illinois. These data are provided for informational purposes only.

[2]USCS, unified soil classification system; AASHTO, American Association of State Transportation Officials; W, gravimetric water content; PL, plastic limit; LL, liquid limit; PI, plasticity index; N, blow counts; Qu, unconfined compression test range; P, pocket penetrometer test range; CL,high plasticity; ML, moderate plasticity.

Table 16- 2 Particle size distribution and classification[1] of typical soils in the Villa Grove Quadrangle.

	Classification			Percentage retained on U.S. standard sieve mesh no.									Hydrometer	
	USDA[2]	USCS[3]	AASHTO (group index)	4[4]	10	16	20	40	50	60	100	200	3.9 m	<3.9 m
				Gravel	Sand								Silt	Clay
Peoria Silt	SiC	CL	A-6 (11)	0.8	0.7	-	-	3.5	-	-	7.6	1.0	53	34
Peoria Silt	SiCL	CL	A-7,6 (15)	0	0	-	-	-	-	6	-	10	59	25
Diamicton Brown sandy clay Batestown Member	SC	CL	A-6 (8)	3	1.2	0.7	-	-	8.8	-	9.8	6.5	30.7	38.7
Diamicton (glacial till) Brown silty clay Batestown Member	SiC	CL	A-6 (12)	-	-	-	1.4	2.5	-	-	6.3	2.1	50.0	37.8
Diamicton (glacial till) Gray silty clay Batestown Member	SiC	CL	A-6 (10)	-	-	-	2.9	3.8	-	-	9.2	4.5	39.8	39.8
Diamicton (glacial till) Batestown Member Gray silty clay + sand	SiC + sand	CL-ML	A-4 (0)	0	2.9	-	-	8.5	-	-	12.3	9.2	36.5	30.6

[1]Source: Composited particle size and classification data are courtesy of S. Robinson, Illinois Department of Transportation District 5, Paris, Illinois; D. Hambley and J. Nelson, Graef, Anhalt, Schloemer, Chicago, Illinois; and D. Kerns, Hanson Engineers, Incorporated, Springfield, Illinois. Data are provided for informational purposes only.

[2]USDA, United States Department of Agriculture; USCS, unified soil classification system; AASHTO, American Association of State Transportation Officials; Si, silty; C, clay; L, loam.

[3]CL, high plasticity; ML, moderate plasticity.

[4]U.S. standard sieve mesh numbers (size): 4 (4.75 mm), 10 (2 mm), 16 (1.19 mm), 20 (840 µm), 40 (420 µm) 50 (300 µm), 60 (250 µm), 100 (149 µm), 200 (74 µm).

REFERENCES

Battelle Memorial Institute and Hanson Engineers, Inc., 1990a, Alternative investigation studies, Clark County, Illinois, v. II—Geological and geotechnical investigations; Illinois low-level radioactive waste disposal facility siting project, various paginations.

Battelle Memorial Institute and Hanson Engineers, Inc., 1990b, Martinsville alternative site, Clark County, Illinois, v. I–IV; Illinois low-level radioactive waste disposal facility siting project, various paginations.

Berg, R.C., and C.C. Abert, 1999, General aquifer sensitivity map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ-Villa Grove-AS, scale 1:24,000.

Federal Emergency Management Agency, National Flood Insurance Program, 1985, Flood insurance rate map—Douglas County, Illinois (unincorporated areas): Community-Panels Numbers 170194-0050-B and 170194-0125-B, effective date March 4, 1985, scale 1:24,000.

Fraser, G.S., and J.C. Steinmetz, 1971, Deltaic sedimentation in glacial Lake Douglas: Illinois State Geological Survey, Circular 466, 12 p.

Hallbick, D.C., and J.B. Fehrenbacher, 1971, Soil survey of Douglas County, Illinois: Champaign, Illinois, Soil Conservation Service, U.S. Department of Agriculture, and Illinois Agricultural Experiment Station, University of Illinois at Urbana-Champaign, 81 p., 52 plates.

Hansel, A.K., R.C. Berg, and C.C. Abert, 1999, Surficial geology map, Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ-Villa Grove-SG, scale 1:24,000.

Heigold, P.C., and T.H. Larson, 1990, Seismicity of Illinois: Illinois State Geological Survey, Environmental Geology Note 133, 20 p.

Soil Survey Division Staff, 1993, Soil Survey Manual: U.S. Department of Agriculture, Handbook 18 [revision], 437 p.

Stohr, C., 2001, Construction conditions, natural hazards of the Villa Grove Quadrangle, Douglas County, Illinois: Illinois State Geological Survey, IGQ-Villa Grove-EG scale 1:24,000.

Wendland, W.M., 1998, A ground frost climatology for Illinois: Transactions of the Illinois State Academy of Science, v. 91, nos. 1 and 2, p. 57–67.

Chapter 17

Mineral Resources

Zakaria Lasemi, Donald G. Mikulic, C. Pius Weibel,
and Dylan P. Canavan[1]
with contributions by
Randall E. Hughes, John M. Masters, and Philip J. DeMaris

Normally buried thousands of feet below the surface in central Illinois, aggregate-quality Silurian and Devonian carbonates (mostly dolomite) lie near the surface along the Tuscola Anticline (Bell 1943), a major domal structure in the western part of the Villa Grove Quadrangle. Erosion along this anticline during the last 250 million years removed thousands of feet of shale, siltstone, limestone, and sandstone, making the Silurian-Devonian carbonates economically accessible to mining for valuable high-quality construction aggregate. In the quadrangle, the potential for economically mining aggregate resources diminishes eastward, away from the Tuscola Anticline, where the Silurian-Devonian carbonates are buried progressively deeper under younger Paleozoic sedimentary rocks and Quaternary glacial sediments.

Other potential resources in the Villa Grove Quadrangle include local surficial deposits of clay, sand, and gravel, as well as Pennsylvanian age deposits of coal, clay, shale, and sandstone. The northernmost part of a widespread coal deposit reaches into the eastern portion of the quadrangle (Chapter 18). Widespread oil shows, an abundance of reservoir-quality reef rocks, and the existing nearby Hays oil field suggest that hydrocarbon reservoirs may exist within some of the Paleozoic rocks in the quadrangle. Oil may not be present in rocks along the axis of the Tuscola Anticline, however, because of erosional truncation of the New Albany Shale and Mississippian-Pennsylvanian cap rocks.

AGGREGATE RESOURCES

The three-dimensional mapping project in the Villa Grove Quadrangle has revealed significant reserves of crushed stone. High-quality aggregate resources, which are relatively rare elsewhere in central Illinois, include only Paleozoic limestones and dolomites. Sand and gravel resources, which are commonly associated with Quaternary age glacial deposits, are not a major source of aggregate in the quadrangle.

Limestone and dolomite constitute a major portion of the middle and lower Paleozoic rock units in Illinois. Although deeply buried in most areas in central Illinois, these rocks are at or near the surface at the margins of the Illinois Basin in western, southern, and northern Illinois, where they provide significant quantities of aggregate used to build and maintain the state's infrastructure. In addition to their use as crushed stone, limestone and dolomite have a variety of other uses, including the manufacture of portland cement and lime, neutralization of acid mine drainage, flue-gas desulfurization in coal-burning power plants, agricultural lime, and many other industrial applications.

Most Paleozoic rocks mined for construction aggregate in central Illinois (e.g., Charleston and Nokomis quarries) belong to the limestones within the Pennsylvanian System. These limestones are generally thin (20 to 40 feet), and large areas must be stripped during extraction. Thick, aggregate-quality Paleozoic limestones and dolomites occur near the surface in only a few places in central Illinois. These areas generally are the sites of major geologic structures (domes or anticlines) such as the Tuscola Anticline in the western part of the quadrangle.

Sand and Gravel Resources

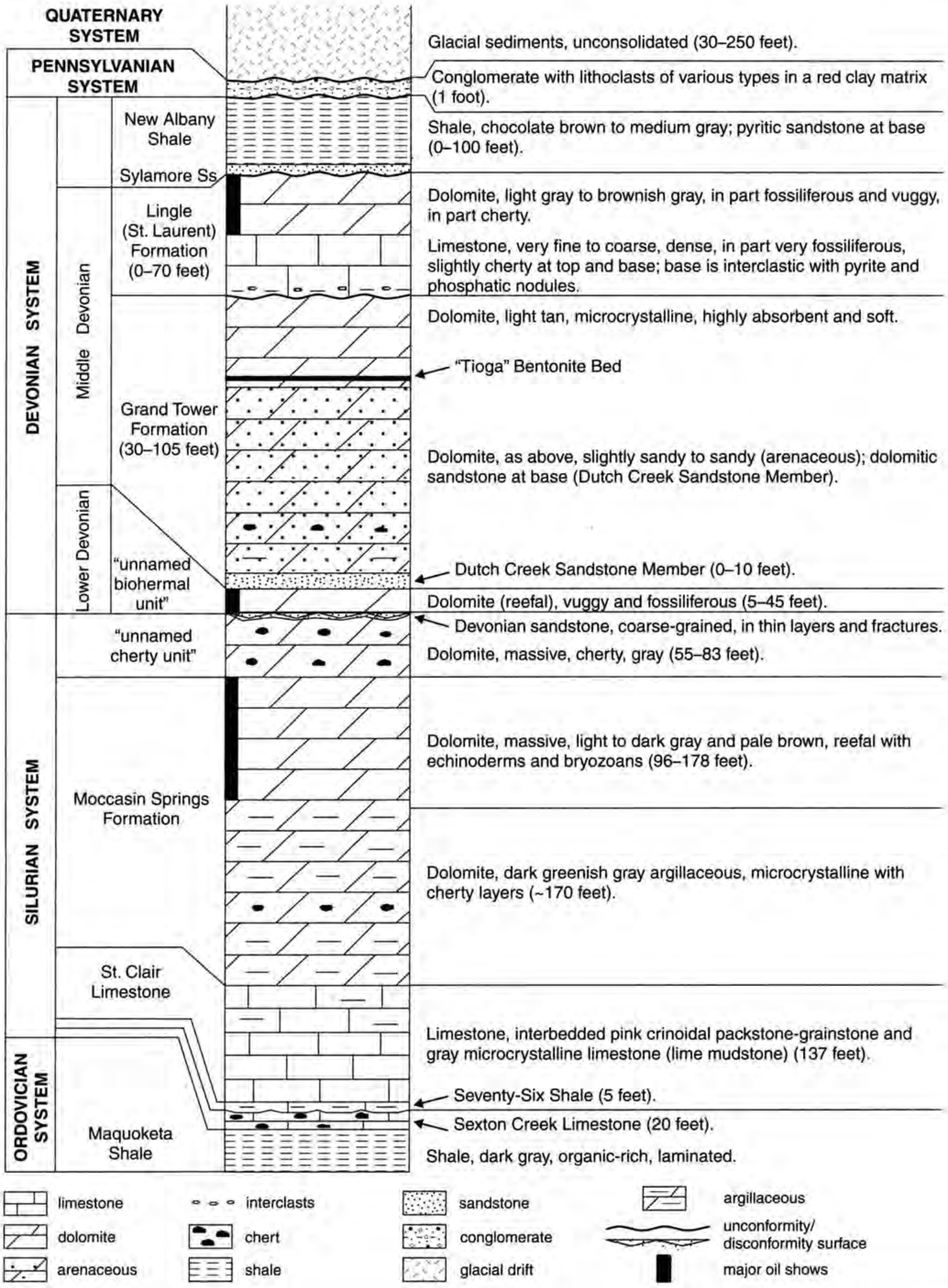
Erosion during the Pennsylvanian and subsequent periods, especially carving by glaciers during the Quaternary Period, left behind an irregular bedrock topography covered by poorly sorted glacial sediments. These sediments locally contain sand and gravel lenses that are potential aggregate resources or aquifers. To be economical, sources of medium- to high-quality aggregates (such as concrete sand) and deposits of sand and gravel generally should be at least 10 feet thick with a ratio of deposit to overburden thickness of about 2:1. Minable deposits should also be at least 20 acres in area. In the Villa Grove Quadrangle, known sand and gravel deposits are either too thin or too deeply buried to be economically mined. Thin sand and gravel deposits present near the surface along the Embarrass River and elsewhere in the quadrangle (see Chapter 15) may provide small amounts of low-quality aggregate for local use as trench backfill and for roadbase and shoulder work on secondary roads.

Limestone and Dolomite Resources

Bedrock sedimentary rocks present in the Villa Grove Quadrangle range in age from Pennsylvanian through Cambrian. The Pennsylvanian, Mississippian, and parts of the Middle Devonian rocks have been erosionally truncated along the Tuscola Anticline in the western part of the quadrangle. As a result of this erosion, aggregate-quality Silurian-Devonian carbonates (fig. 17-1) occur near the land surface along the axis of the

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

[1]Present address: Department of Geology, 245 Natural History Building, University of Illinois, 1301 W. Green, Urbana, IL 62801.



QUATERNARY SYSTEM
PENNSYLVANIAN SYSTEM
DEVONIAN SYSTEM
Middle Devonian
Lower Devonian
New Albany Shale
Sylamore Ss
Lingle (St. Laurent) Formation (0–70 feet)
Grand Tower Formation (30–105 feet)
"unnamed biohermal unit"
SILURIAN SYSTEM
"unnamed cherty unit"
Moccasin Springs Formation
St. Clair Limestone
ORDOVICIAN SYSTEM
Maquoketa Shale
Glacial sediments, unconsolidated (30–250 feet).
Conglomerate with lithoclasts of various types in a red clay matrix (1 foot).
Shale, chocolate brown to medium gray; pyritic sandstone at base (0–100 feet).
Dolomite, light gray to brownish gray, in part fossiliferous and vuggy, in part cherty.
Limestone, very fine to coarse, dense, in part very fossiliferous, slightly cherty at top and base; base is interclastic with pyrite and phosphatic nodules.
Dolomite, light tan, microcrystalline, highly absorbent and soft.
"Tioga" Bentonite Bed
Dolomite, as above, slightly sandy to sandy (arenaceous); dolomitic sandstone at base (Dutch Creek Sandstone Member).
Dutch Creek Sandstone Member (0–10 feet).
Dolomite (reefal), vuggy and fossiliferous (5–45 feet).
Devonian sandstone, coarse-grained, in thin layers and fractures.
Dolomite, massive, cherty, gray (55–83 feet).
Dolomite, massive, light to dark gray and pale brown, reefal with echinoderms and bryozoans (96–178 feet).
Dolomite, dark greenish gray argillaceous, microcrystalline with cherty layers (~170 feet).
Limestone, interbedded pink crinoidal packstone-grainstone and gray microcrystalline limestone (lime mudstone) (137 feet).
Seventy-Six Shale (5 feet).
Sexton Creek Limestone (20 feet).
Shale, dark gray, organic-rich, laminated.
limestone
dolomite
arenaceous
interclasts
chert
shale
sandstone
conglomerate
glacial drift
argillaceous
unconformity/ disconformity surface
major oil shows

anticline. Where overburden is thin (less than 50 feet), the Silurian-Devonian carbonates are economically accessible by open pit quarrying (e.g., Tuscola Stone Company quarry). Eastward, away from the anticline, these units are buried progressively deeper under Pennsylvanian, Mississippian, and Upper Devonian strata and Quaternary glacial sediments (fig. 17-2).

Bedrock units with aggregate resource potential in the Villa Grove Quadrangle include the Middle Ordovician, Upper Silurian, Lower Devonian, and Middle Devonian strata (fig. 17-1). The aggregate-quality Silurian-Devonian carbonates (mostly dolomite) are approximately 350 feet thick in the western part of the quadrangle but reach up to 450 feet thick in the eastern two-thirds of the quadrangle. The variation in thickness of the Silurian-Devonian carbonates is caused by the truncation of the upper part of the Middle Devonian carbonates along the Tuscola Anticline and local thickening caused by development of reefs in the Upper Silurian.

Middle Ordovician carbonates The Middle Ordovician age Galena-Plattville carbonates are usable as high-quality aggregate. These units, which underlie the Maquoketa Shale (200 to 225 feet thick), are too deeply buried (approximately 1,100 to 2,100 feet) in the quadrangle to be economically mined at present.

Silurian carbonates Silurian dolomites and limestones are deeply buried throughout all but a small part of the Villa Grove Quadrangle, and rocks that are suitable for crushed stone aggregate occur only in the upper half of the 580-foot-thick section of the Silurian in this quadrangle (fig. 17-1). The uppermost portion of the Silurian is being quarried at the Tuscola Stone Company quarry.

Three sections of the Silurian provide good-quality aggregate: (1) the basal part of the Sexton Creek-St. Clair Limestones, (2) the reef portion of the Moccasin Springs Formation, and (3) an uppermost unnamed cherty dolomite. The Sexton Creek Limestone (20 feet) underlies the Seventy-Six Shale(?), a 5-foot-thick argillaceous unit beneath the St. Clair Limestone. Little information is available for these lower Silurian units. The Sexton Creek and lower St. Clair may be potential aggregate sources, but it is unlikely that these strata would be quarried in the quadrangle because of the great depth at which they occur and the excessively thick overburden of the overlying, shaley, non-reef Moccasin Springs. The reef portion of the Moccasin Springs interval, which is composed of massive to thick-bedded, porous, crystalline, oil-stained dolomite, ranges from 90 to 180 feet thick. The cherty unit consists of 55 to 83 feet of very cherty, thick-bedded dolomite. Its upper surface is irregular and unconformable, whereas its lower boundary drapes over the underlying reefal Moccasin Springs, which accounts for most of the variation in thickness.

Figure 17-1 Generalized stratigraphic column for the western part of the Villa Grove Quadrangle based on VGDH-2 (ISGS core 14845, A.E. Kleiss No. VGDH-2, NW SW NW, Sec. 30, T16N, R9E, Douglas County). To the east of the quadrangle, the New Albany Shale thickens and is overlain by thick Mississippian (Borden Siltstone) and Pennsylvanian rocks.

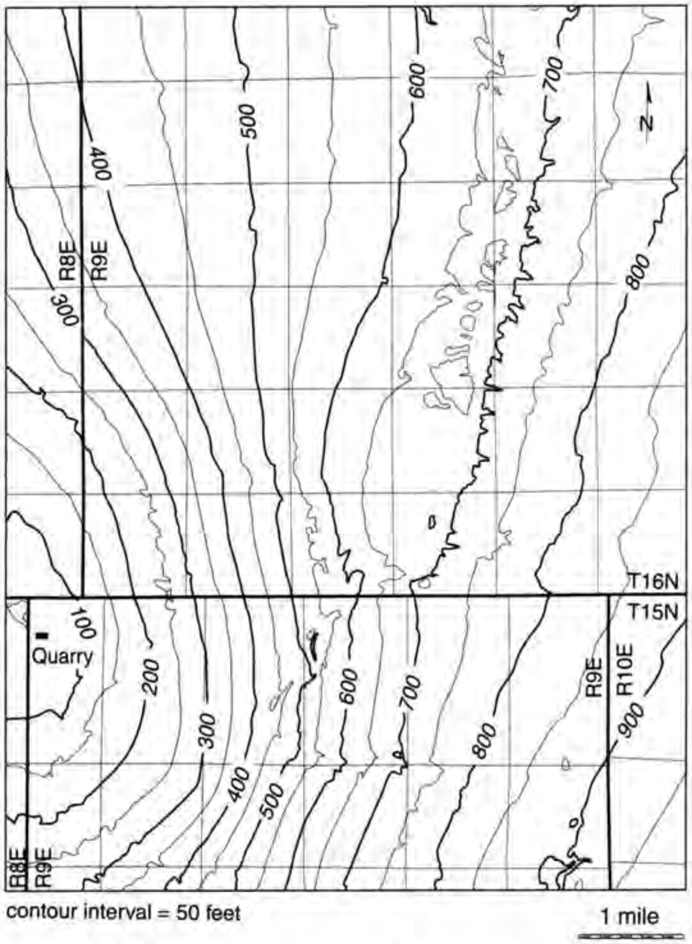


Figure 17-2 Thickness of consolidated and unconsolidated material overlying the Lingle (St. Laurent) Formation.

The remaining lower Silurian rocks in the area are generally unsuitable as aggregate. Most of the non-reef portion of the 235-foot-thick Moccasin Springs is a shaley to very argillaceous limestone. The St. Clair, which is 137 feet thick, is a fairly pure limestone at the base, but argillaceous partings become increasingly more common toward the top, where the St. Clair grades into the overlying Moccasin Springs.

Lower Devonian carbonates A vuggy, reef-type dolomite (informally referred to as in this report as the biohermal unit; Chapter 8) underlies the Dutch Creek Sandstone Member and unconformably overlies the Silurian Dolomite. The dolomite is about 25 feet thick in the Tuscola quarry, but ranges between about 5 and 45 feet thick elsewhere in the quadrangle. The dolomite is very dense and is an excellent source of high-quality aggregate for asphalt or concrete. It is fossiliferous and contains abundant fossil molds. This unit is heavily stained with oil in some areas, which may affect the usefulness of the rock for concrete manufacture.

Middle Devonian carbonates Middle Devonian aggregate resources in the Villa Grove Quadrangle include (1) the Dutch Creek Sandstone Member of the Grand Tower Formation, (2) the Grand Tower Formation, and (3) the Lingle (St. Laurent)

The Grand Tower Formation is mostly a soft, light gray and tan, microcrystalline dolomite. It is mostly slightly sandy to sandy. This dolomite is generally too soft to provide high-quality construction aggregate. It is, however, useable as road-base material to maintain secondary roads and as agricultural lime. The Dutch Creek Sandstone Member at the base is generally dolomitic and dense, and quality is good enough for most construction purposes. The Lingle consists of two major lithofacies: a limestone facies in the lower part and a dolomite facies in the upper part. Except for some thin, cherty and/or argillaceous intervals, both the lower and upper Lingle facies are generally good enough in quality for most construction purposes. In the Tuscola quarry, the upper dolomite facies of the Lingle has been truncated.

OTHER RESOURCES

Clay resources Clay-rich materials that are useful for pond liners, landfill liners and covers, and similarly engineered barriers and berms can be obtained where the Quaternary Equality, Lemont, Glasford, and Banner Formations are close enough to the surface to be mined (see Chapter 11). These same clay materials and bedrock shales could be used to manufacture ceramic products. However, the Quaternary materials are generally not the materials of choice in Illinois, and new ventures of this type generally require an additional source of profitability, such as a low-cost source of natural gas.

Coal resources The eastern part of the quadrangle includes the northern extension of one or more coal deposits. Some of these coals constitute the largest known remaining deposits of low- to medium-sulfur coal in the state (see Chapter 18).

Oil and gas resources The Tuscola Anticline has created favorable conditions for the development of structural traps and hydrocarbon reservoir development (Bristol and Prescott 1968). Although Silurian and Devonian dolomites have significant oil shows, the chance of finding hydrocarbons in these rocks is minimal along the Tuscola Anticline in the western part of the quadrangle because the New Albany Shale, an important hydrocarbon-reservoir seal, has been eroded away. Away from the Tuscola Anticline axis, however, local structures, especially reefs in the Lower Devonian and Upper Silurian strata, have excellent potential for hydrocarbon reservoir and seal development. These reefs are very porous and permeable and have excellent shows of oil. Well data are too sparse to permit assessment of the size and distribution of these reefs at this time. Additional drilling and seismic, gravity, or magnetic data might provide a better understanding of the location of these potential reef-related reservoirs, especially in the central and eastern part of the quadrangle where the New Albany Shale is still present.

Porous and permeable dolomites with significant oil shows include (1) the dolomitic facies of the upper part of the Lingle, (2) the Dutch Creek Sandstone, (3) the Lower Devonian biohermal unit, and (4) the Upper Silurian reefal dolomite. The Grand Tower Dolomite is a very porous, microcrystalline dolomite, but has low permeabilities. Except for some minor bleeding of oil in core samples, significant oil shows are rarely found in this dolomite.

Some potential for the development of a hydrocarbon reservoir in the Upper Ordovician Kimmswick Limestone (Trenton) occurs along the crest of the Tuscola Anticline. The Maquoketa Shale overlies the Kimmswick Limestone and is a source of hydrocarbons and an excellent seal for them. The Hays oil field, located on the Tuscola Anticline west of the Villa Grove Quadrangle, has produced some large quantities of oil from the Kimmswick in the past (Bristol and Prescott 1968), and additional recoverable reserves may be present.

REFERENCES

Bell, A.H., 1943, Subsurface structure of the base of the Kinderhook-New Albany Shale in central and southern Illinois: Illinois State Geological Survey, Report of Investigations 92, 13 p.

Bristol, H.M., and R. Prescott, 1968, Geology and oil production in the Tuscola area, Illinois: Illinois State Geological Survey, Circular 424, 34 p.

Chapter 18

Coal Resources

Colin G. Treworgy

Coal provides more than 60% of electrical generation nationwide and remains an important part of the Illinois economy. The largest coal deposits east of the Mississippi are in Illinois, and the coal industry is a major provider of high-wage jobs downstate. Accurate estimates of the amount of coal resources available for mining are needed for planning by federal and state agencies, local communities, utilities, mining companies, companies supplying goods and services to the mining industry, and other energy consumers and producers. Identifying the best and most accessible deposits can help improve target investment, research, and development.

The factors that restrict access to coal differ greatly in importance, depending on the site. One of the first steps in this project has been determining the site-specific criteria used to calculate the amount of attainable coal. These factors include the thickness of the seam, its quality, its depth, the amount of bedrock over it, and the proportion of the bedrock to glacial materials above it. In addition, cultural factors such as towns, roads, and cemeteries make resources unavailable. Three-dimensional mapping is essential for assessing the factors that determine coal quality and availability.

The Villa Grove Quadrangle is on the northwest edge of the largest known remaining deposit of low- to medium-sulfur coal (0.5% to 2% sulfur, as-received basis) in Illinois (fig. 18-1). Analysis of a core drilled by the Illinois State Geological Survey (ISGS) confirmed the low-sulfur content of the Herrin Coal in the quadrangle (table 18-1). The area of lowest sulfur coal is believed to extend for several miles to the south and east of the quadrangle.

More than 100 million tons of Herrin Coal are present in the eastern and southern parts of the Villa Grove Quadrangle, but adverse geologic conditions may make much of this resource uneconomical to mine using current technology. Taking geologic and land use factors into consideration, only about 6 million tons of coal are available for mining, and another 13 million are available but have less than ideal mining conditions. The best conditions for underground mining are in the extreme southeastern part of the quadrangle and probably extend to the south beyond the quadrangle boundary. Although the depth and thickness of the seam are favorable for surface mining, the thickness of glacial and alluvial overburden relative to bedrock overburden is considerably greater than has been stripped for mining elsewhere in the state, which may present problems for highwall stability.

The southeastern half of the quadrangle is underlain by at least three other seams: the Springfield, Houchin Creek, and Colchester Coals. Data on these coals are limited, and only the Springfield Coal resources have been mapped. The Springfield Coal is too thin for underground mining, but surface mining may be economical in a limited area near the center of the south edge of the quadrangle.

COAL RESOURCES

Coals are present in the quadrangle in the Pennsylvanian age Carbondale and Tradewater Formations (see Chapters 10 and 17). Core hole VGDH-1, drilled on the southeast edge of the quadrangle, went through 243 feet of Pennsylvanian strata, including four coal seams: the Herrin, Springfield, Houchin Creek, and Colchester (fig. 18-2). These units become thinner to the northwest as they lap onto the La Salle Anticline. Although Pennsylvanian strata at one time covered the entire quadrangle, subsequent erosion removed much or all of the Pennsylvanian rocks from the crest of the anticline and from bedrock valleys. Data available for this area are sufficient for mapping resources of the Herrin and Springfield Coals only. The Houchin Creek and Colchester Coals are believed to be too thin to be of economic interest at this time.

Coal resources were mapped using records from 135 coal- and oil-test holes drilled in and adjacent to the quadrangle (fig. 18-3). The drill holes are concentrated in the southeastern portion of the quadrangle where thick deposits of Herrin Coal are located. Few holes have been drilled for coal exploration in the quadrangle north and west of the Herrin Coal subcrop because of the presumed absence of thick seams.

The subcrop of the Herrin Coal is buried throughout the quadrangle under 50 to more than 100 feet of glacial and alluvial sediments (fig. 18-4). This subcrop of the coal and the thickness of the bedrock overburden (fig. 18-5) were mapped by computer by merging the projected elevation of the Herrin Coal with the elevation of the bedrock surface. Coal elevation was mapped using data from the coal and oil exploration holes (fig. 18-6). The coal rises gently to the west-northwest at a rate of 20 to 40 feet per mile. Elevation of the bedrock surface was mapped

Table 18-1 Analyses of coal from VGDH-1 (ISGS core 14944) (as-received basis) in the Villa Grove Quadrangle.

	Herrin Coal		
	Upper bench	Lower bench	Springfield Coal
Moisture (%)	9.27	10.94	8.71
Ash (%)	12.78	9.14	18.67
Volatile matter (%)	34.72	31.47	31.53
Fixed carbon (%)	43.22	48.44	41.09
Sulfur (%)	4.42	1.09	7.71
Heating value (Btu/lb)	10,926	10,222	11,451

Three-dimensional Geologic Mapping: A Pilot Program for Resource and Environmental Assessment in the Villa Grove Quadrangle, Douglas County, Illinois. Z. Lasemi and R.C. Berg, eds.: Champaign, Illinois, Illinois State Geological Survey, Bulletin 106, 2001, 118 p.

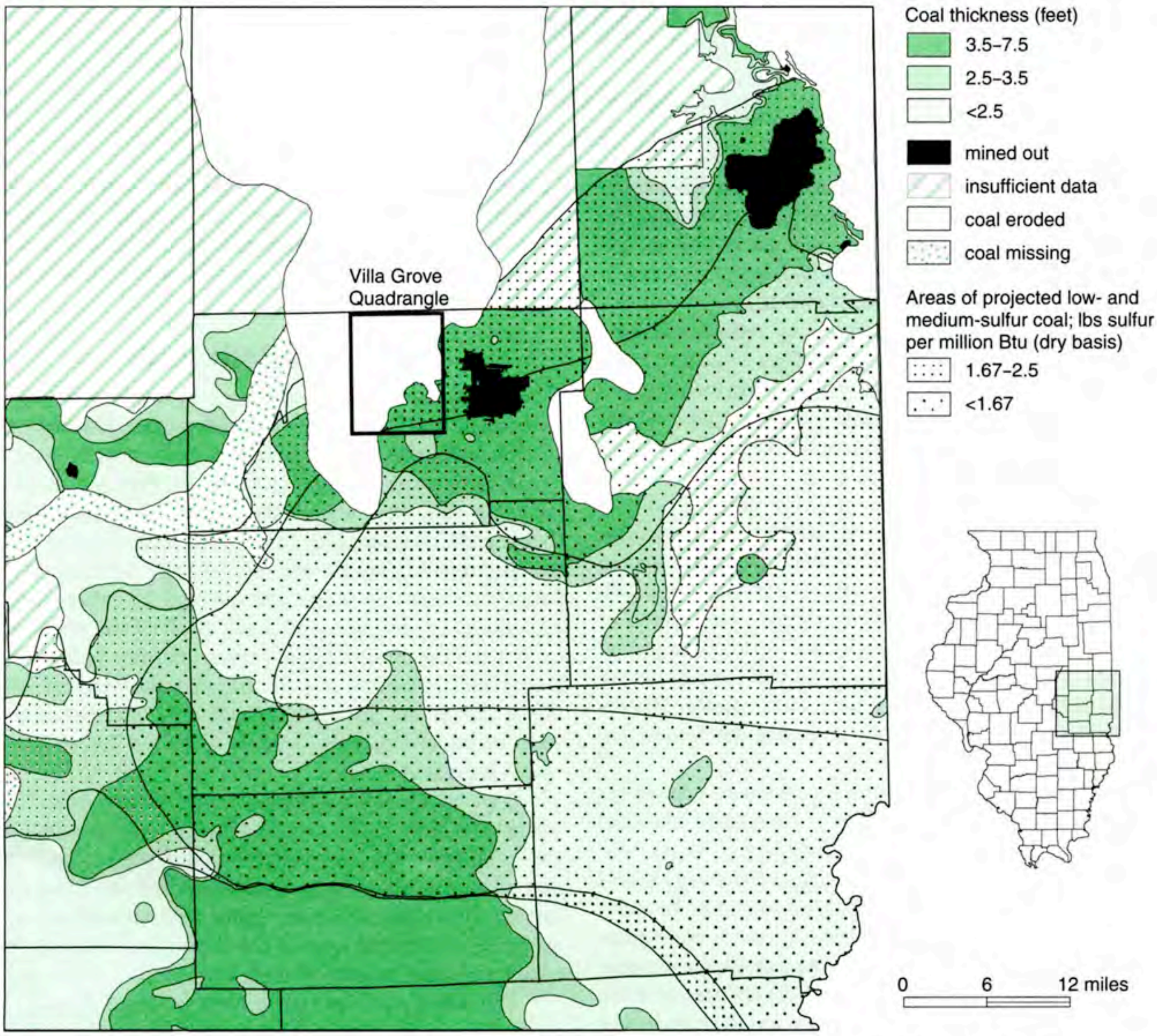


Figure 18-1 Thickness of the Herrin Coal and projected areas of medium- and low-sulfur content in east-central Illinois.

by Weibel using data from water wells and the exploration holes (Chapter 12).

The subcrop of the Springfield Coal was mapped using the same procedure. The structural trend of the Springfield is essentially identical to that of the Herrin, but the coal lies 15 to 25 feet deeper than the Herrin; thus, it crops out slightly farther to the north and west. Because there were fewer control points for the Springfield than for the Herrin, the subcrop line produced by the computer was manually edited to make it consistent with the trend of the Herrin subcrop.

Herrin Coal

The Herrin Coal has been eroded from all but the southeast quarter and the east edge of the Villa Grove Quadrangle, where it ranges in depth from less than 100 feet to about 250 feet (fig. 18-7). Where present, the coal is 6 to 7.5 feet thick, except for a small area of thinner coal near the subcrop southwest of the town of Camargo and along the south margin of the quadrangle (fig. 18-8). The area of 4-foot-thick coal southwest of Camargo is defined by only one drill hole. This entire location may be an anomalously thin spot, or it may indicate that the coal that lay west of this point (but is now eroded) thinned toward the crest of the anticline. The Herrin Coal was mined a few miles to the east of the quadrangle near the town of Murdock from 1946 to 1991.

Along the south margin of the quadrangle, the Herrin Coal is split into two benches separated by a clastic, wedge-shaped deposit of siltstone and shale (fig. 18-9). The split begins as a parting a few inches thick but thickens abruptly from a few inches to more than 35 feet thick over a distance of 0.25 mile (fig. 18-10). This clastic wedge is part of a larger wedge of clastic sediments deposited in east-central Illinois during and immediately after formation of the Herrin Coal (Treworgy and Jacobson 1985). The wedge separating the two coal benches

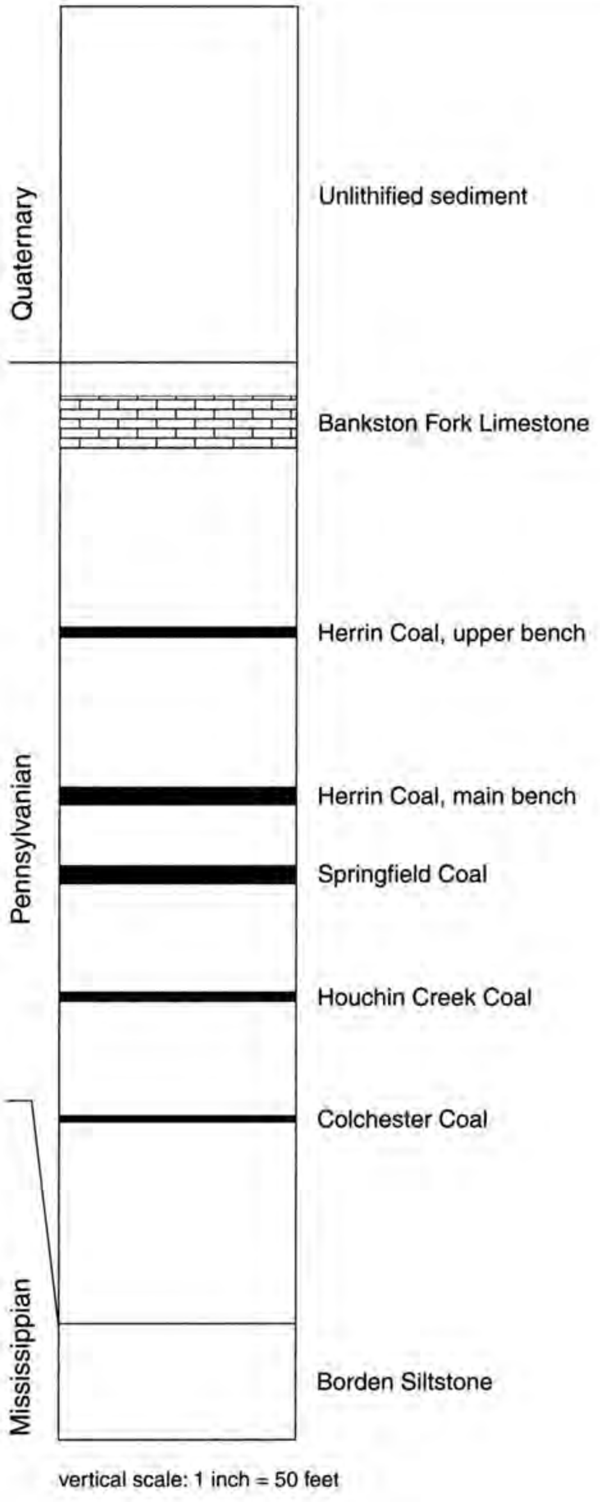


Figure 18-2 Generalized stratigraphy of the VGDH-1 core (ISGS core 14944), Douglas County.

represents a period of sediment deposition during the time of peat accumulation in the Herrin Coal swamp. After this event, clastic sediment deposition ceased or shifted to another area of the swamp, and the peat swamp in the Villa Grove Quadrangle redeveloped over the clastic sediment. When sedimentation resumed again in the area, it buried the peat swamp with tens of feet of clastics. In other areas of Illinois, away from this area of clastic deposition, the Herrin swamp was flooded by marine water, and the peat deposits were eventually covered by a sequence of marine black shales and limestones.

The lower or main bench of Herrin Coal in this area is 3.2 to 4.5 feet thick and can be traced southward for about 35 miles to the south edge of the clastic wedge near the town of Toledo, where the two benches come together into a single seam. The upper bench, approximately the upper one-third of the seam, is 2 to 3.3 feet thick in the southeast corner of the quadrangle, but, farther west, it is only about 1 foot thick (fig. 18-11). Data from drill holes about 1 mile south of the quadrangle indicate that the upper bench is slightly thicker than 0.5 foot in that area. The upper bench can be traced about 2 miles south of the north edge of the clastic wedge. Beyond this point, the upper bench is either absent or too thin to be detected using the type of drilling records available for this area. The upper bench is again observable to the south where the clastic wedge separating the two benches of coal thins and eventually pinches out.

Previous studies have shown that the formation in coal of pyritic sulfur (the main form of sulfur in Illinois coals) is limited where thick accumulations of clastic sediments were deposited on the peat before or shortly after transgression of the coal swamp by marine water (Gluskoter and Simon 1968). Medium- and low-sulfur contents have been reported for the Herrin Coal under this clastic wedge in mines to the east near Murdock and Georgetown, as well as in cores from drill holes to the south near Charleston and Toledo. The ISGS drilled a core hole (VGDH-1, ISGS core 14944) at the south edge of the quadrangle to obtain, among other things, samples of the two benches of Herrin Coal. At the core site, the upper bench of coal was 2.3 feet thick and the lower bench 3.65 feet thick (as measured from the geophysical log). The benches were separated by 39.1 feet of shale and siltstone (a complete log of the core is given in Appendix 1). Analysis of these samples showed that the sulfur content of the upper bench is typical of high-sulfur coals in Illinois (4.4%, as-received basis), whereas, for Illinois, the lower bench is very low in sulfur content (1.1%; table 18-1). Where both benches are together in the nearby mines at Murdock, as well as in other mines to the east, the sulfur content of the coal ranges from less than 2% to nearly 3%. Although most of the mining at Murdock was conducted in the thick coal north of the split, some mining followed the main bench of the coal southward below the split for several hundred feet. The sulfur content of the coal dropped from more than 2% to about 1.4% over a distance of about 200 feet from the edge of the split.

Springfield Coal

The Springfield Coal is present 15 to 25 feet below the Herrin Coal. Although almost 4 feet thick in the VGDH-1 core, other drilling records indicate that the Springfield is commonly less than 3 feet thick throughout its occurrence in the quadrangle (fig. 18-12). In the VGDH-1 core, the Springfield Coal had a sulfur content of 7.7%, an anomalously high value for this coal

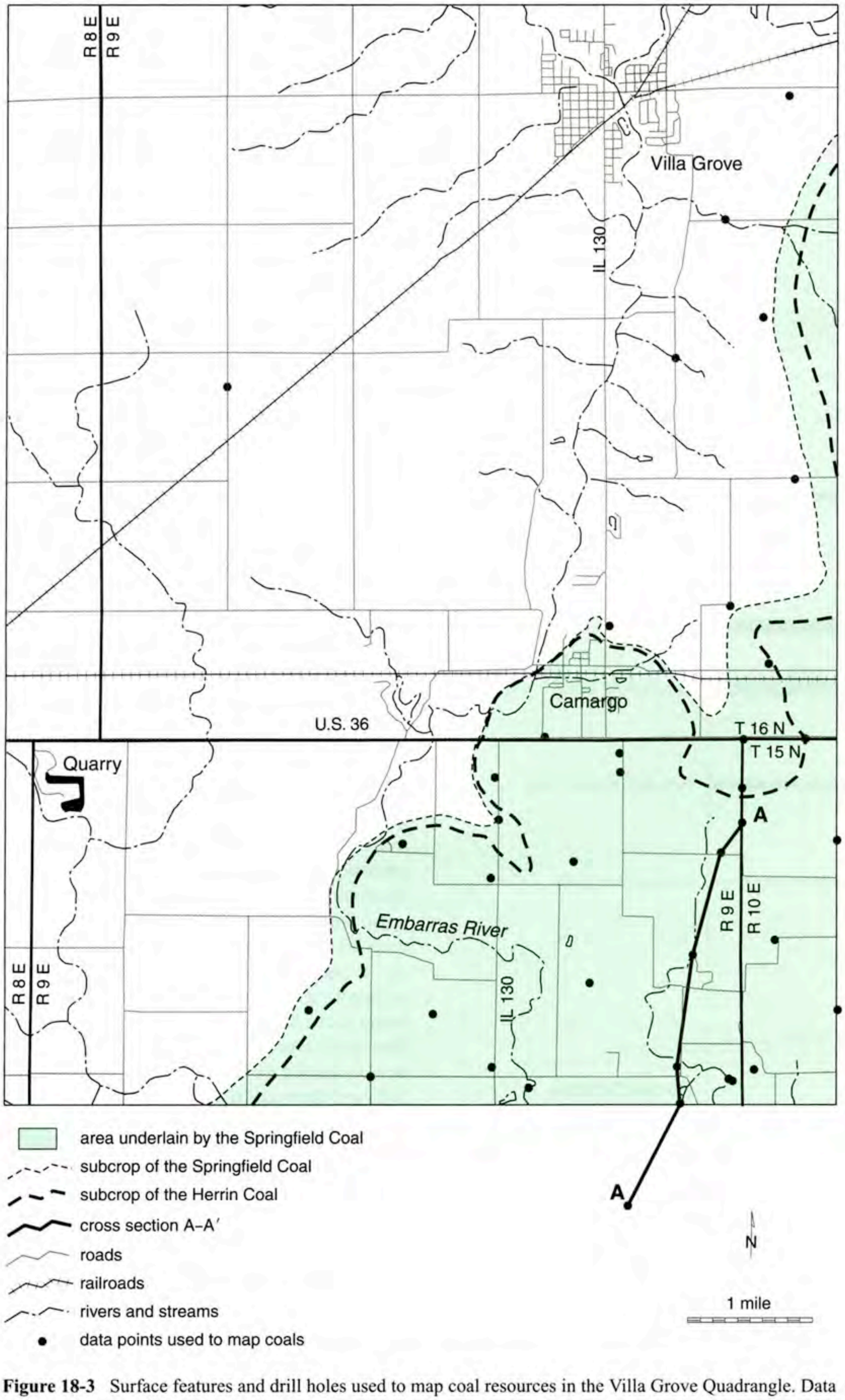


Figure 18-3 Surface features and drill holes used to map coal resources in the Villa Grove Quadrangle. Data points adjacent to the quadrangle are not shown.

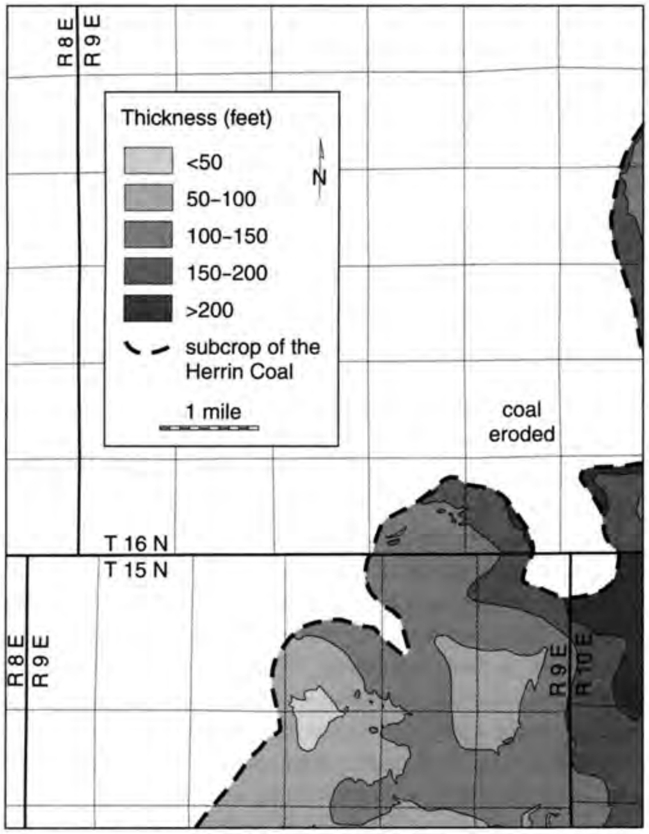


Figure 18-4 Thickness of glacial drift and alluvium overlying the Herrin Coal in the Villa Grove Quadrangle.

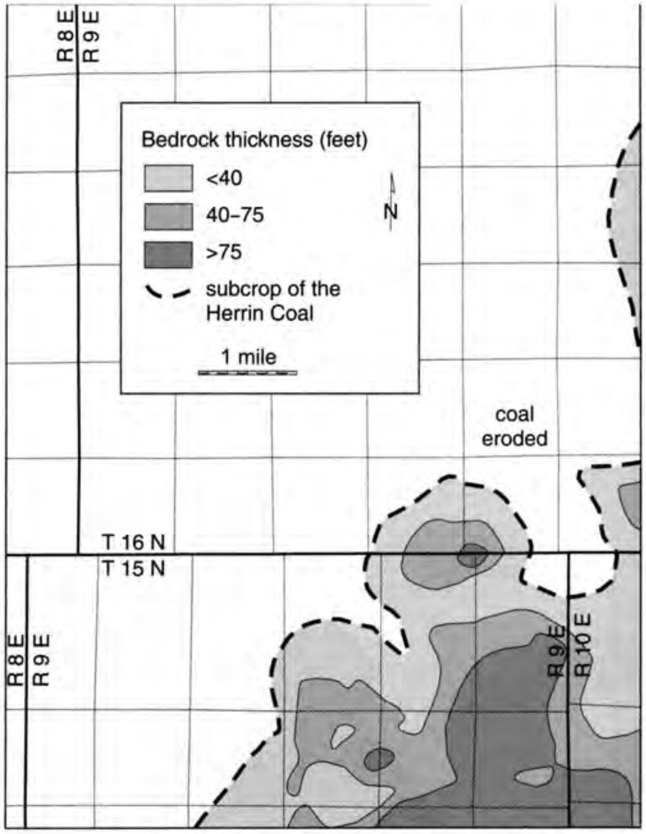


Figure 18-5 Thickness of bedrock above the Herrin Coal in the Villa Grove Quadrangle.

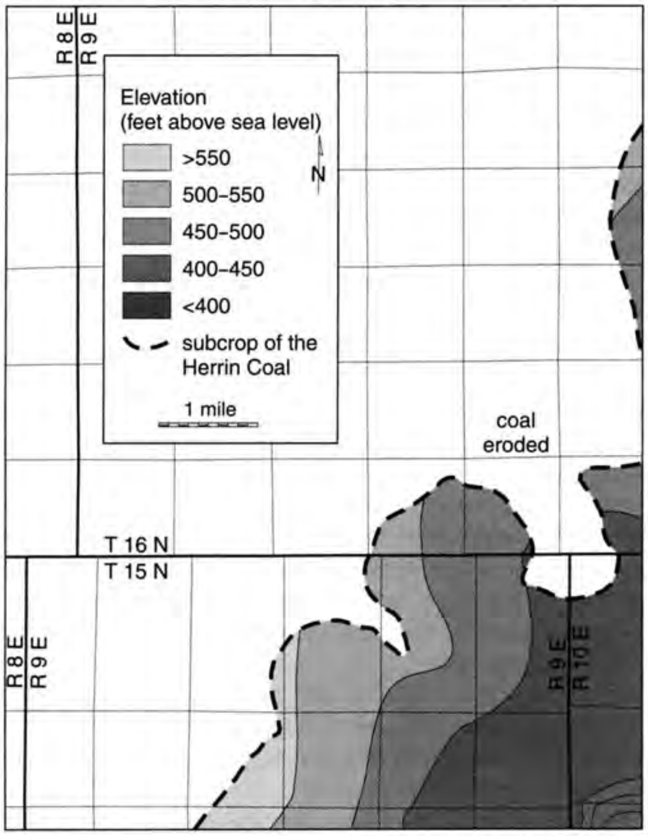


Figure 18-6 Elevation of the Herrin Coal in the Villa Grove Quadrangle.

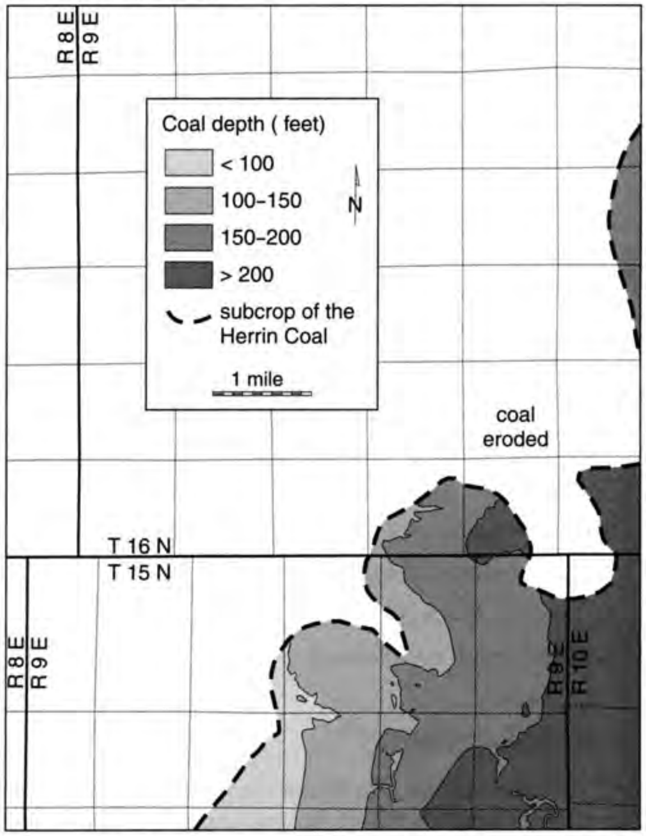


Figure 18-7 Depth to the top of the Herrin Coal in the Villa Grove Quadrangle.

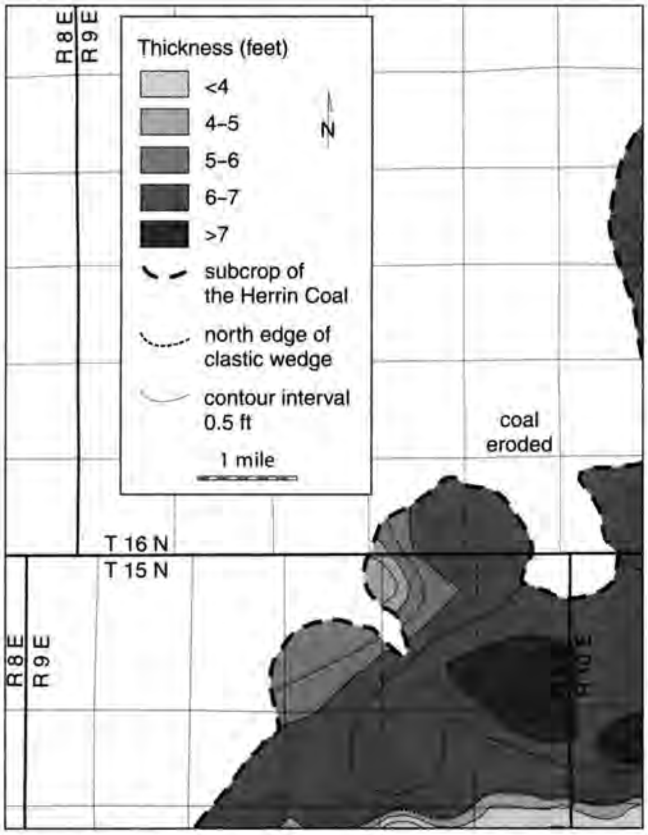


Figure 18-8 Thickness of the main bench of the Herrin Coal in the Villa Grove Quadrangle.

in this area. The coal throughout the quadrangle is expected to have a sulfur content in the range of 3% to 5%.

AVAILABILITY OF COAL RESOURCES FOR MINING

Millions of tons of coal resources remain in and adjacent to the Villa Grove Quadrangle. When, or whether, these resources will be mined depends on a variety of interrelated factors:

- land use and ownership
- geologic characteristics and mining conditions of the resources compared with those of other coal resources
- demand for coal
- cost and supply of coal from existing mines
- cost and supply of competing fuels
- environmental regulations
- transportation infrastructure
- coal quality
- mining technology

Many of these factors can change over time in ways that can either enhance or reduce the attractiveness of resources for mining, and most of these factors are beyond the scope of this chapter.

A starting point for understanding the potential for mining these resources is to examine the factors of land use and geologic characteristics compared with the coal resources currently being mined in the state. This analysis indicates the availability of these resources for mining under current technological and market conditions.

Criteria to Determine Coal Availability

A series of studies conducted by the ISGS identified criteria that limit the availability of coal in Illinois (Treworgy and Bargh 1984; Treworgy et al. 1994, 1995, 1996a,b, 1997, 1998; Jacobson et al. 1996). These studies were based on interviews with more than 45 mining engineers, geologists, and other experts from mining companies, consulting firms, and government agencies involved in the Illinois mining industry. Criteria for the restrictions that limit the availability of the Herrin and Springfield Coals for mining in the Villa Grove Quadrangle were developed from these studies (table 18-2).

Economic and social factors may not be absolute restrictions on mining. Companies can choose to mine in areas of unstable roof or floor conditions, if they are willing to bear the higher operating costs, production interruptions and delays, and lower employee morale. It is possible to surface-mine through most roads and to mine under small towns if a company is willing to invest the time and expense necessary to gain the approval of governing units and landowners and to mitigate damages. Previous economic and social conditions have at times enabled companies to mine in areas where some factors are now restrictive. The current, highly competitive price environment in the coal industry, which makes it profitable to mine only coal that can be produced at a low cost, is expected to prevail indefinitely in the Illinois Basin.

Criteria for assessing the availability of coal vary depending on the extraction method. Surface mining uses earth-moving equipment, such as scrapers and draglines, to remove the earth material overlying the coal. Underground mining utilizes a shaft or slope entry to access the coal seam and extracts the coal without removing the overlying rocks. Some shallow resources may be minable by either surface or underground mining methods.

Restrictions on mining fall into two categories: technological and land use (table 18-2).

Technological restrictions Technological restrictions are geologic conditions (e.g., seam thickness, size of mining block, stripping ratio) that, given current technology and mining practices, significantly raise the cost of mining. Companies may mine under these conditions in limited areas. In the Villa Grove Quadrangle, the major technological restrictions are related to the overburden—the thickness and composition of earth materials overlying the coal.

Thick deposits of glacial drift or alluvial sediment can restrict surface mining because of their potential to slump into the pit, fail under the weight of large draglines, or allow excessive groundwater to flow into the pit (fig. 18-13). A minimal amount of bedrock overburden ensures that the coal is not weathered and provides stable material to hold the toe of the spoil pile.

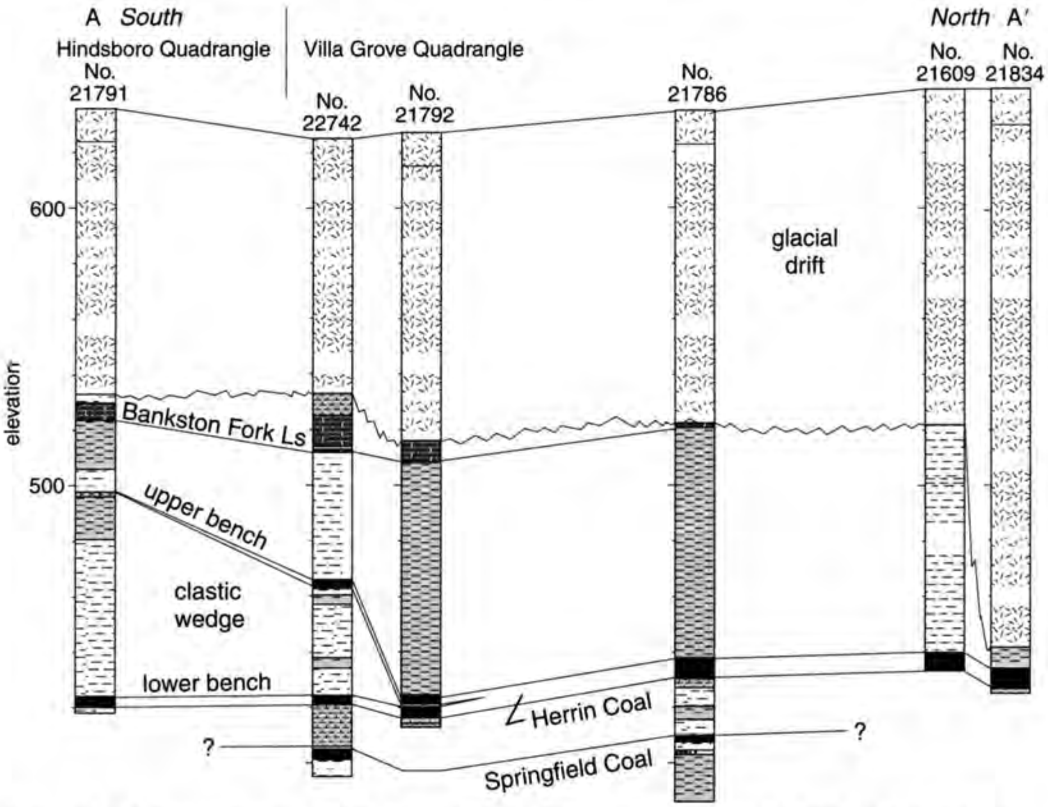


Figure 18-9 Cross section A–A′ in the Villa Grove Quadrangle. See figure 18-3 for the location of the line of the cross section. See figure 18-3 for line of cross section and horizontal scale.

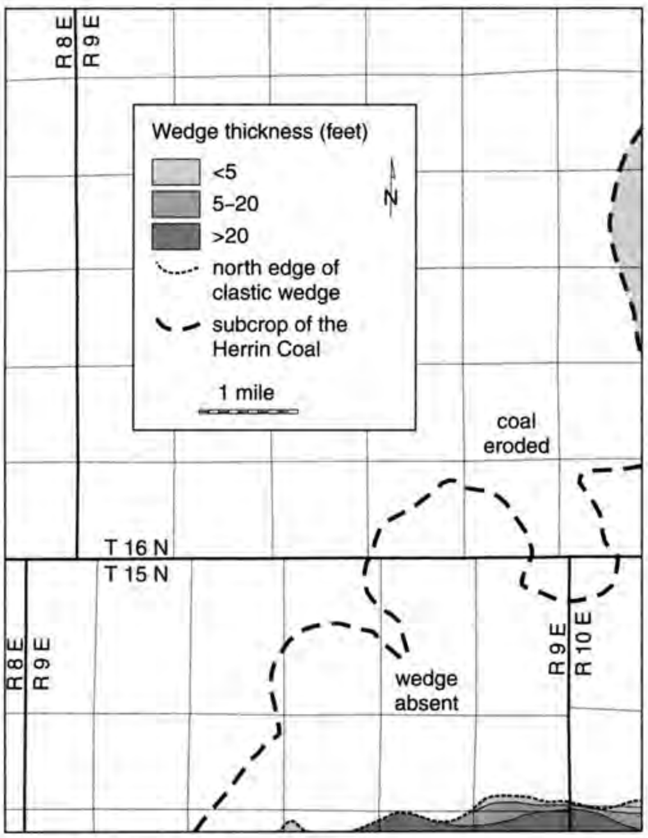


Figure 18-10 Thickness of the clastic wedge in the Herrin Coal in the Villa Grove Quadrangle.

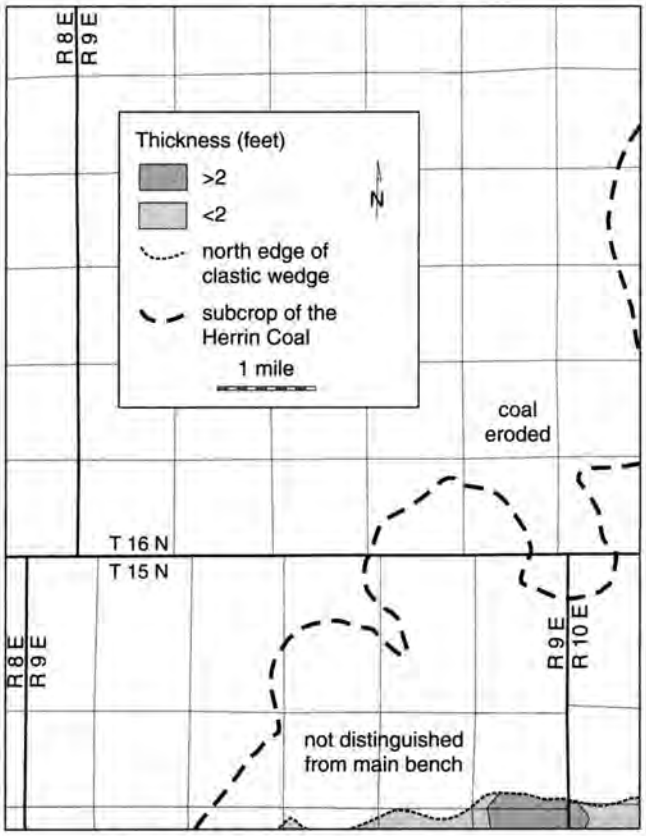


Figure 18-11 Thickness of the upper bench of the Herrin Coal in the Villa Grove Quadrangle.

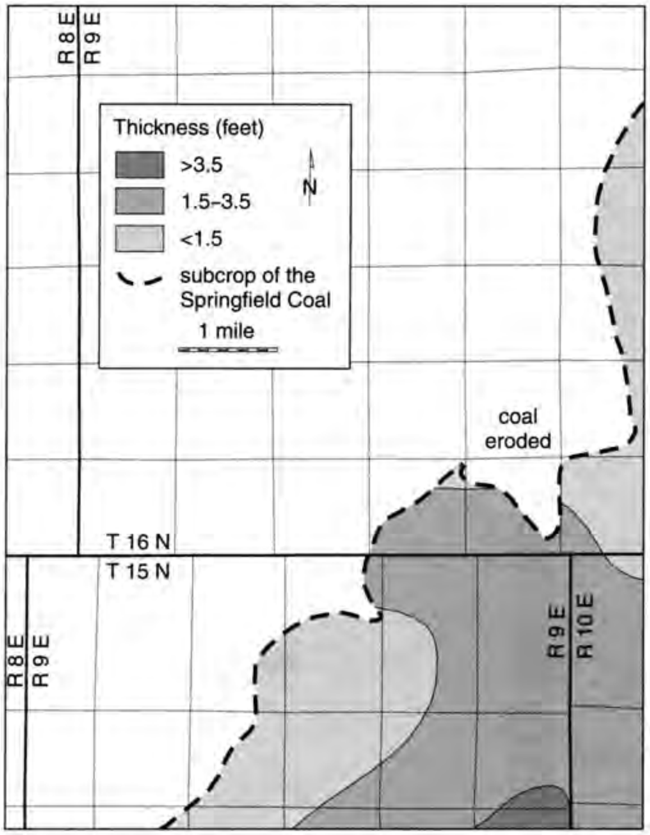


Figure 18-12 Thickness of the Springfield Coal in the Villa Grove Quadrangle.

Table 18-2 Conditions that restrict the availability of coal for mining in the Villa Grove Quadrangle.

SURFACE MINING
Technological restrictions (coal is restricted if it fails to meet these conditions)
- Minimum seam thickness
  - Main seam: 1 foot
  - Overlying seams: 0.5 foot
- Maximum depth: 200 feet
- Maximum unconsolidated overburden
  - Coal <100 feet deep: two-thirds of total overburden
  - Coal >100 feet deep: one-half of total overburden
- Minimum bedrock cover: 10 feet
- Stripping ratio (cubic yards of overburden per ton of raw coal)
  - Maximum: 25:1
  - Maximum average: 20:1
- Minimum size of mine reserve (raw tons in place)
  - Individual block: 600 thousand
  - Total tonnage: 12 million

Land use restrictions
- No mining within 100 feet of
  - Cemeteries
  - Railroads
  - Federal and state highways
  - Churches
  - Pipelines
- No mining within 0.5 mile of towns

UNDERGROUND MINING
Technological restrictions (coal is restricted if it fails to meet these conditions)
- Minimum seam thickness: 3.5 feet
- Minimum bedrock cover:
  - If Bankston Fork Limestone present: 40 feet
  - If Bankston Fork Limestone absent: 75 feet
  - Reduced extraction if bedrock is greater than minimum thickness but bedrock to drift ratio < 1
- Minimum size of mining block: 40 million tons in place
- Reduced extraction within 200 feet of Embarras River floodplain

Land use restrictions
- No mining within 200 feet of
  - Towns
  - Cemeteries
  - Churches

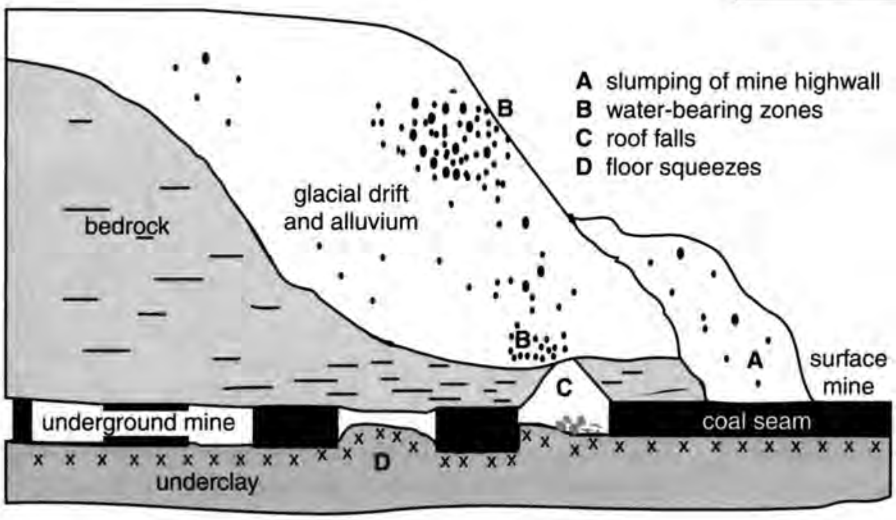


Figure 18-13 Problems encountered in surface and underground mines that have thick glacial and alluvial sediments overlying thin bedrock overburden in the Villa Grove Quadrangle (from Treworgy et al. 1998).

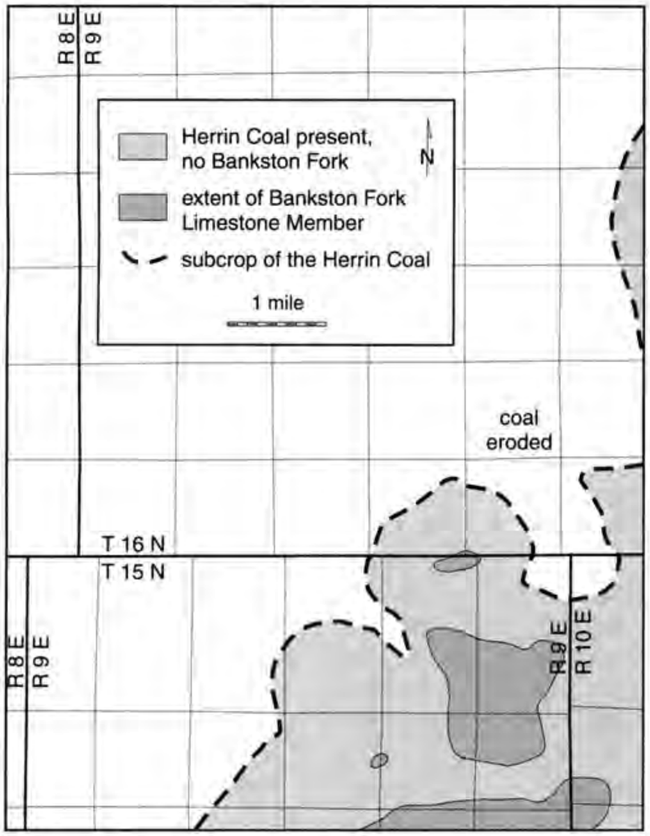


Figure 18-14 Distribution of the Bankston Fork Limestone in the Villa Grove Quadrangle.

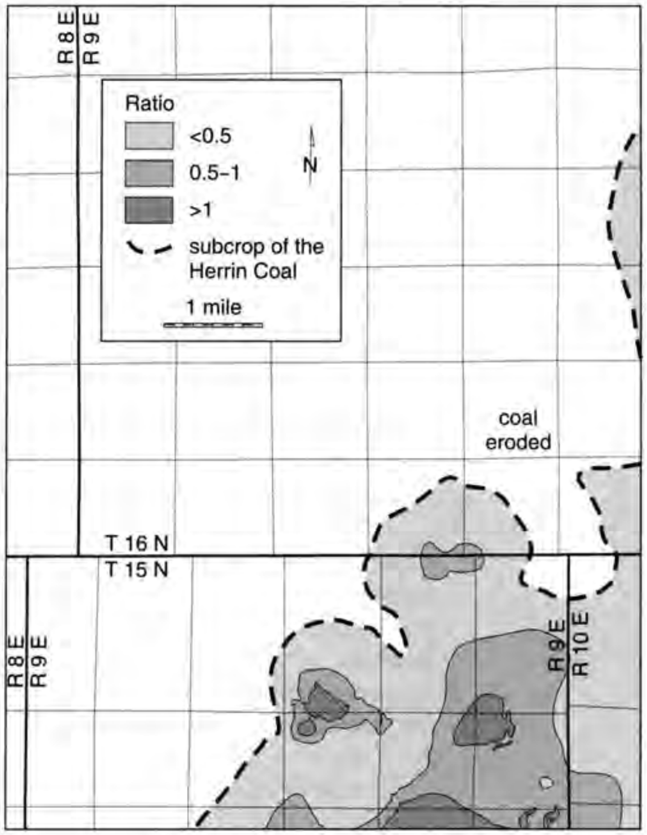


Figure 18-15 Ratio of the thickness of bedrock to glacial and alluvial overburden above the Herrin Coal in the Villa Grove Quadrangle.

Underground mining requires adequate bedrock overburden to support the mine roof and seal the mine against water seepage from the surface. The amount of bedrock overburden required depends on the composition of the bedrock and the thickness of the overlying glacial and alluvial sediments. Less bedrock is necessary if competent strata such as limestones are present. More bedrock is necessary if the glacial and alluvial material is thick. Underground mines in areas where thick glacial and alluvial sediments overlie thin bedrock overburden commonly experience roof falls, floor squeezes, and water influxes.

A minimum of 40 feet of bedrock is necessary for underground mining in the Villa Grove Quadrangle, according to our estimates, which are based on mining conditions in other areas that have similar overburden conditions. In areas where the Bankston Fork Limestone Member is missing, the bedrock consists entirely of shales and siltstones, and a minimum of 75 feet of bedrock is necessary (figs. 18-5 and 18-14). Even in areas that meet these criteria, larger than normal pillars will be necessary, and hence extraction will be reduced, to provide extra insurance against roof control problems in areas where the bedrock to drift ratio is less than 1 (fig. 18-15). The mines at Murdock commonly experienced problems with roof and floor stability in areas where this ratio was less than 1.

Land use restrictions Sometimes land use is restricted by surface developments or environmental features that are specifically protected from mining by law or are typically too expensive for mining companies to disturb. For example, Illinois law allows mining within 100 feet of dwellings, but because of the cost of mitigating the effects of dust, noise, and vibrations from mining, most companies choose to keep operations at least 0.5 mile from towns. In the Villa Grove Quadrangle, the only major land use restriction is Camargo. Roads, railroads, cemeteries, and pipelines restrict minor amounts of resources.

AVAILABLE RESOURCES

Of the 107 million tons of resources in the quadrangle, about 6 million tons (6%) are available for mining, and another 13 million tons (13%) are available with conditions (table 18-3). Land use restricts 7 million tons (7%) of the resources, and technological factors restrict 81 million tons (75%) of the resources. Almost all of the available resources are in the main bench of the Herrin Coal. A few thousand tons of the resources of the upper bench of the Herrin Coal and of the Springfield Coal are available for surface mining, but only if mined in combination with the main bench of the Herrin Coal.

About 63 million tons of the resources in the quadrangle are less than 200 feet deep and therefore potentially surface minable. However, only 5% of these (3 million tons) are available for surface mining, and an additional 1 million tons (2%) are available if mined in combination with the underlying or overlying seams

Table 18-3 Available and restricted coal resources in the Villa Grove Quadrangle, in thousands of tons and percentage of original resources.

	Herrin Coal Upper bench	Herrin Coal Main bench	Springfield Coal	Total
Original	428	86,010	20,846	107,283
Available		6,071 (7)		6,071 (6)
Available with conditions[1]	26 (6)	12,999 (15)	417 (2)	13,443 (13)
Land use restriction	42 (10)	4,547 (5)	2,607 (13)	7,196 (7)
Technological restriction	360 (84)	62,394 (73)	17,821 (85)	80,574 (75)
Surface minable (0 to 200 feet deep)				
Original	316	56,000	6,751	63,067
Available		2,967 (5)		2,967 (5)
Available with conditions[1]	26 (8)	942 (2)	417 (6)	1,386 (2)
Land use restriction	7 (2)	9,994 (18)	2,607 (39)	12,608 (20)
Towns		7,592 (14)	2,062 (30)	9,654 (15)
Cemeteries		87 (<1)	18 (<1)	105 (<1)
Highways	7 (2)	1,145 (2)	234 (3)	1,386 (2)
Pipelines		936 (2)	231 (3)	1,167 (2)
Railroads		234 (<1)	61 (1)	295 (<1)
Technological restriction	283 (90)	42,097 (75)	3,726 (55)	46,106 (73)
Stripping ratio	283 (90)	7,426 (13)	1,010 (15)	8,718 (14)
Block size		1,104 (2)	3 (<1)	1,106 (2)
Unconsolidated overburden		33,567 (60)	2,714 (40)	36,281 (58)
Underground minable (>40 feet deep)				
Original	397	86,010	14,341	100,747
Available		3,484 (4)		3,484 (4)
Available with conditions[1]		11,791 (14)		11,791 (12)
Land use restriction	42 (11)	4,547 (5)	146 (1)	4,735 (5)
Towns		4,291 (5)		4,291 (4)
Cemeteries	42 (11)	235 (<1)	127 (1)	403 (<1)
Churches		21 (<1)	19 (<1)	40 (<1)
Technological restriction	355 (89)	66,187 (77)	14,195 (99)	80,737 (80)
Coal <3.5 feet thick	355 (89)	80 (<1)	2,519 (18)	2,598 (3)
Thin bedrock		65,161 (76)	6,006 (42)	71,168 (71)
Block size		946 (1)	5,670 (40)	6,971 (7)

[1]Available for surface mining only if mined in combination with an underlying or overlying seam, or available for underground mining but the ratio of bedrock to unconsolidated overburden is less than 1:1 and difficult mining conditions may be encountered.

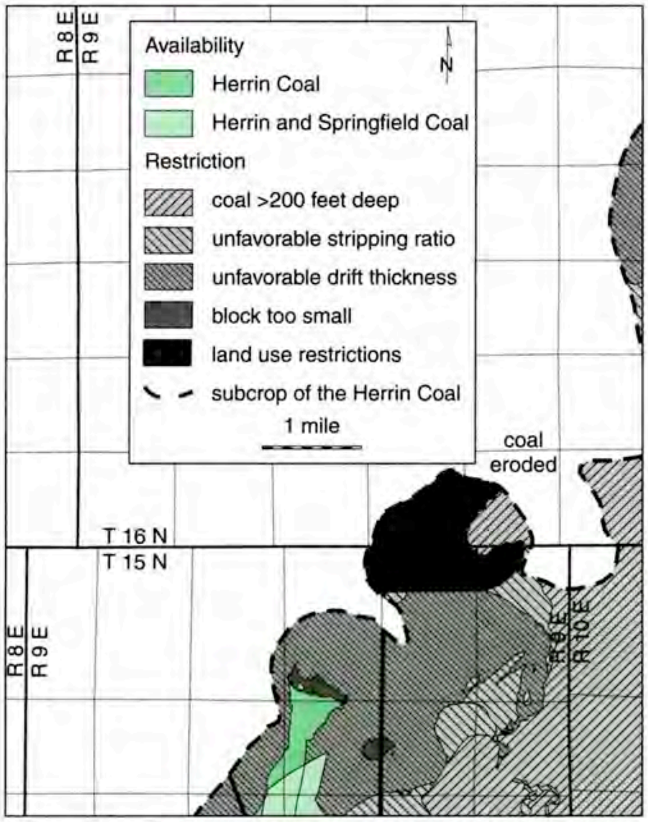


Figure 18-16 Resources of Herrin and Springfield Coals available for surface mining in the Villa Grove Quadrangle.

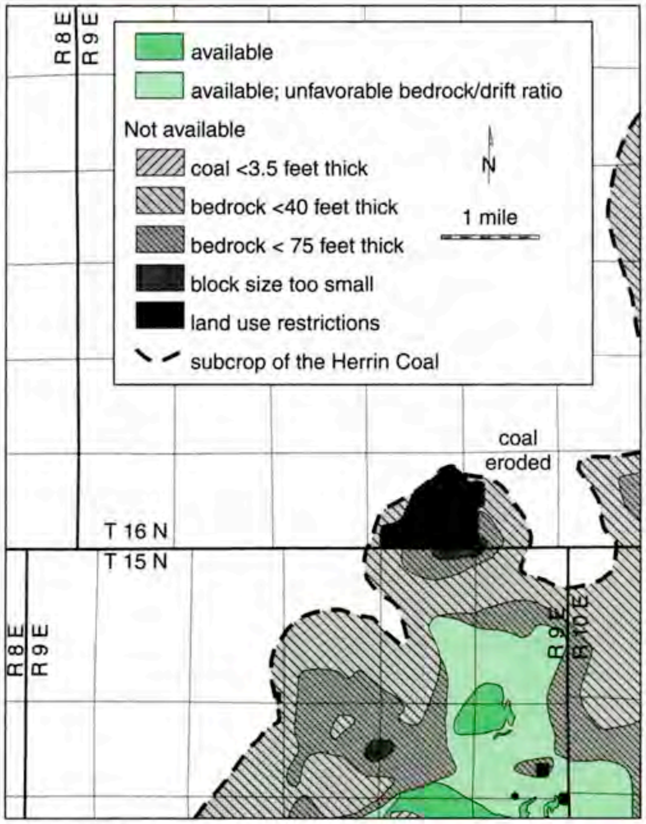


Figure 18-17 Resources of Herrin Coal available for underground mining in the Villa Grove Quadrangle.

(fig. 18-16). The remainder are restricted primarily by the thickness of the unconsolidated overburden (58%), high stripping ratio (14%), and towns (15%).

Almost 101 million tons of the resources are at least 2.3 feet thick and are considered underground minable. Of these, about 3 million tons (4%) are available for underground mining (fig. 18-17). Another 12 million tons (12%) are available with conditions. Although these resources have the minimum thickness of bedrock overburden, the ratio of bedrock to drift overburden is less than 1, so it may be necessary to leave larger pillars or mine smaller rooms to prevent mining problems.

REFERENCES

Gluskoter, H.J., and J.A. Simon, 1968, Sulfur in Illinois coals: Illinois State Geological Survey, Circular 432, 28 p.

Jacobson, R.J., C.G. Treworgy, and C. Chenoweth, 1996, Availability of coal resources for mining in Illinois, Mt. Carmel Quadrangle, southeastern Illinois: Illinois State Geological Survey, Illinois Minerals 114, 39 p.

Treworgy, J.D., and M.H. Bargh, compilers, 1984, Coal resources of Illinois, Herrin (No. 6) Coal, Illinois State Geological Survey map, scale, 1:500,000.

Treworgy, C.G., C.A. Chenoweth, and M.H. Bargh, 1995, Availability of coal resources for mining in Illinois—Galatia Quadrangle, Saline and Hamilton Counties, southern Illinois: Illinois State Geological Survey, Illinois Minerals 113, 38 p.

Treworgy, C.G., C.A. Chenoweth, and R.J. Jacobson, 1996a, Availability of coal resources for mining in Illinois, Newton and Princeville Quadrangles, Jasper, Peoria, and Stark Counties: Illinois State Geological Survey, Open File Series 1996-3, 47 p.

Treworgy, C.G., C.A. Chenoweth, and M.A. Justice, 1996b, Availability of coal resources for mining in Illinois, Atwater, Collinsville, and Nokomis Quadrangles, Christian, Macoupin, Madison, Montgomery, and St. Clair Counties: Illinois State Geological Survey, Open File Series 1996-2, 33 p.

Treworgy, C.G., C.A. Chenoweth, J.L. McBeth, and C.P. Korose, 1997, Availability of coal resources for mining in Illinois, Augusta, Kewanee. North, Mascoutah, Pinckneyville, and Roodhouse East Quadrangles, Adams, Brown, Greene, Henry, Perry, Schuyler, and St. Clair Counties: Illinois State Geological Survey, Open File Series 1997-10, 72 p.

Treworgy, C.G., G.K. Coats, and M.H. Bargh, 1994, Availability of coal resources for mining in Illinois, Middletown Quadrangle, central Illinois: Illinois State Geological Survey, Circular 554, 48 p.

Treworgy, C.G., and R.J. Jacobson, 1985, Paleoenvironments and distribution of low-sulfur coal in Illinois, in A.T. Cross, ed., Compte Rendu of Ninth International Congress on Carboniferous Stratigraphy and Geology, 1979, v. 4, Economic Geology, Coal Oil and Gas: Carbondale, Illinois, Southern Illinois University Press, p. 349–359.

Treworgy, C.G., J.L. McBeth, C.A. Chenoweth, C.P. Korose, and D.L. North, 1998, Availability of coal resources for mining in Illinois, Albion South, Peoria West, Snyder-West Union, Springerton and Tallula Quadrangles, Clark, Edwards, Hamilton, Menard, Peoria, Sangamon and White Counties: Illinois State Geological Survey, Open File Series 1998-1, 92 p.

Appendixes

Appendix 1

Core description Prosser No. VGDH-1
2,670 feet EL, 4,300 feet SL, Sec. 13, T15N, R9E
Villa Grove Quadrangle, Douglas County
County No. 22742
Core No. 14944
Surface elevation 618 feet ETM

Logged by A. Hansel (Quaternary System), P. DeMaris, and C.P. Weibel (Mississippian-Pennsylvanian Systems) with input from C. Treworgy for interval above the Springfield Coal. For the pre-Quaternary interval, nominal depths were corrected by detailed remeasurement, matched with electric logs.

	Depth below surface Top (feet)	Bottom (feet)	Thickness (feet)
QUATERNARY SYSTEM			
Wisconsin Episode			
Mason Group			
Henry Formation (?)			
Lost core.	0.0	16.0	16.0
Illinois Episode			
Glasford Formation (?)			
Diamicton.	16.0	17.5	1.5
Pre-Illinois Episode			
Banner Formation			
Diamicton; silt loam; calcareous; olive-gray, dark gray/very dark gray, and gray; silt, fine sand, and gravel from 22.5 to 23 feet.	17.5	28.0	10.5
Diamicton; silt loam; calcareous; very dark gray brown/dark gray; stonier than above.	28.0	36.5	8.5
Diamicton; loam; calcareous; dark gray; gradational contact to above, fairly uniform.	36.5	49.0	12.5
Diamicton; silt loam; calcareous; very dark gray-brown.	49.0	63.0	14.0
Sand, fine.	63.0	63.5	0.5
Diamicton; loam; calcareous; dark gray; less uniform than above.	63.5	83.0	19.5
Diamicton; loam; calcareous; very dark gray; organic sediments with wood; becomes darker, siltier, and contains more organics with depth.	83.0	91.4	8.4
PENNSYLVANIAN SYSTEM			
Top of bedrock (and base of Pleistocene) is at 91.4 feet. Loss of weathered bedrock at top is estimated to be 0.45 foot.			
Gray shale or claystone, weathered in top 3.5 feet, medium gray, weak, non-calcareous at top, slightly calcareous 5.5 feet down, carbonaceous bits and mica flakes at 7 feet down; angular (unconformable) contact to top of limestone; faintly bedded in bottom 2 feet. (Grades up into loss interval.)	91.85	99.78	7.93
Limestone (Bankston Fork), light gray to gray-brown, argillaceous, some bioclasts, deformed shale laminae in top 7 feet, styolites 7 to 10 feet down, yellow recrystalized zone in gray matrix near base. Angular unconformity at top of unit is marked by oxidized sienna nodules and greenish gray clay; unconformable contact with underlying siltstone shown by thin brown band and irregular start of carbonate mineralization; 0.02 foot loss.	99.78	113.11	13.33
Siltstone, argillaceous at top, light to medium greenish gray, moderate bioturbation in top 8 feet, very thin to laminated bedding. No loss.	113.11	122.94	9.83
Shale and siltstone, medium gray shale with interbeds of light gray siltstone, bedding flat to wavy; non-calcareous, bioturbation rare; siltstone lenses scarce at base; carbonaceous debris common on bedding; 0.10 foot total losses.	122.94	139.59	16.65

Shale, silty, well-laminated, medium gray, no bioturbation seen, flat bedding, few carbonaceous laminae, some FeS oxidizing, grades downward to silty shale with siltstone lenses; no loss.	139.59	149.69	10.10
Shale, medium gray, coarsely laminated with some siltstone lenses, very finely carbonaceous (most fragments under 1 mm) and some silt; flat bedding, no deformation. 25% light siltstone laminae in top 2 feet, less common downward, grades to non-silty in bottom third; small FeS nodule at mid-unit, several more nodules in a narrow zone just above base; 0.02 foot loss.	149.69	155.73	6.04
Shale, medium gray, non-silty, scattered plant debris, including several large pieces on bedding planes in bottom 1.1 foot of unit. Two siderite bands and a few weakly sideritized zones present. Bottom 0.21 foot is dark gray shale, non-silty, finely carbonaceous. No loss.	155.73	158.95	3.22
Coal (Herrin, upper bench), normally bright-banded; sharp contact to claystone below (samples: C35863, maceration: 3314C).	158.95	160.95	2.00
Claystone (underclay); light gray, some pyrite; slickensided; coalified plant with 12° dip near top; grades quickly downward to (no loss):	160.95	161.82	0.87
Shale, medium gray, faintly banded, typically 10 to 15% siltstone laminae, a few thin siltstone lenses near base; grades to (no loss):	161.82	164.16	2.34
Siltstone, light gray, moderately micaceous, gradational top and fairly abrupt basal contact with medium-gray shale. Siltstone shows ripple bedding with low-angle truncation in upper 3 feet; more finely laminated, more clay, and more planar-bedded in bottom 1 foot. Clay films contain fine carbonaceous matter. Extraction damage and spinoff losses total 0.55 feet.	164.16	168.03	3.87
Shale, medium gray, with scattered siltstone laminae throughout (less that 10% total), slightly irregular bedding; some low-angled truncations of bedding, mostly in top half, one probable leaf compression 0.57 foot down; grades downward to:	168.03	174.79	6.76
Shale and siltstone; shale with finely interlaminated siltstone, estimated 60% shale/40% siltstone; low-angle truncation common, some ripple bedding, bed becomes 50%/50% in bottom 6 feet; grades to (0.25 foot loss):	174.79	186.79	12.00
Siltstone and shale; siltstone interbedded with shale, estimated 70% siltstone, 30% shale, top contact gradational; basal contact is fairly abrupt, but may be conformable. Siltstone is irregularly bedded, shows some deformation and injection of fine sandstone into cracks in interbedded shale. Spinoff and breakage loss of 0.50 foot.	186.79	191.13	4.34
Shale, light to medium gray; finely laminated throughout; siderite bands in bottom 4 feet; fine siltstone laminae from 1 to 6 feet down from top. Several organic-rich plant debris zones in bottom 1 foot of unit, two have siderite nodule bands within them; 0.3 foot of finely carbonaceous shale just above spinoff at coal contact (0.08-foot loss just above coal).	191.13	200.70	9.57
Coal (Herrin, lower bench), normally bright-banded (samples C35864, maceration 3314B).	200.70	204.32	3.62
Claystone (thick underclay sequence) dark gray carbonaceous claystone with plant compressions at top; grades to medium gray over 1 foot; top 4 feet is weak because of nodular structure; unit is slightly calcareous from 2.5 to 5 feet down; unit shows some mineralizations crossing bedding and occasional small brown (siderite?) nodules throughout; unit is faintly to clearly mottled throughout. Bottom 3 feet appears to be an altered and weak shale, light gray with greenish cast; has irregular vertical planes mineralized with reddish brown mineral. Grades downward to (estimated 0.40 foot loss):	204.32	212.06	7.74
Shale, medium to dark gray, weak; mottled in top 3 feet, although less than above unit, linguloid brachiopods in top foot; unit slightly calcareous except near black shale; some carbonaceous traces above fairly sharp contact with (no loss):	212.06	218.43	6.37
Shale ("Turner Mine"), black, laminated but non-fissile, weak, medium-angle slickensides; irregular pyritic? mineralized zone at base (0.12 foot); probably complete, but loss interval, bottom contact borders loss interval.	218.43	218.98	0.55
Shale (Dykersburg facies?), medium to dark gray; includes loss at top; slickensided at middle; finely carbonaceous, some plant fragments on bedding planes; poorly bedded;	218.98	219.38	0.40

non-fissile; very pyritic in bottom 0.04 foot; probable pectin seen; contact to coal not seen (estimated 0.21 foot loss at top):			
Coal (Springfield), sub-bright-banded, with clay dike at base (clay injected into coal as a result); (samples C35865, maceration 3314A).	219.38	223.13	3.75
Claystone (underclay), very dark gray in top 0.15 foot, then obvious core loss, then medium gray claystone with probable root compressions, other carbon traces to 1 foot below coal; moderately friable; scattered slickensides throughout lower 3 feet, grades to light gray in bottom foot (estimated losses 0.15 foot).	223.13	226.50	3.37
Siltstone, calcareous, some dark mineralization throughout interval, some soft-sediment deformation of bedding. Moderately calcitic throughout; weakly sideritized in top 0.35 foot. Dark mineralization strongest at 1 foot from top. No core loss.	226.50	230.77	4.27
Shale, medium gray; well indurated, faintly laminated, non-calcareous except bottom 0.2 feet; bottom 2.5 feet is dark, finely carbonaceous shale that grades up into medium gray shale. Possible rhythmic bedding at 6 feet from base. Dark secondary mineralization occurring on sub-vertical planes with some blebs along bedding. Bedding convergence around streaks/blebs suggests early mineralization. Upper half of unit shows some scattered siltstone laminae, with some thin interbedded siltstone bands near the top contact. No fossils seen. No losses.	230.77	242.91	12.14
Shale, calcitic and fossiliferous at base, grades upward to poorly bedded, mottled shale; zones of crinoid bioclasts at 245.2 and 245 feet. Grades up to stronger, calcareous shale, with fossils becoming less common but whole. Top 0.5 foot of unit returns to poorly indurated calcareous shale that lacks obvious fossils, but has 0.2 foot thick sideritized zone at top.Loss of 0.15 foot from “drill string jam.”	242.91	246.65	3.74
Shale, medium gray; moderately fissile, faintly laminated, two sideritized zones in top foot; a few scattered slickensides. Spinoff loss of 0.08 foot.	246.65	249.47	2.82
Shale, calcareous; carbonaceous at base; very fossiliferous at center with some large dark gray clay-rich clasts mixed with brachiopod valves, crinoids, and other bioclasts. No loss (samples R21143–44).	249.47	249.80	0.33
Shale (Excello), black; finely laminated and fissile throughout, very highly organic throughout; some thin calcitic bands in top 0.15 foot; top 0.03 foot has small marine bioturbation traces; irregular brown mineralization 0.03 to .05 foot above base. No core loss (samples R21879–881).	249.80	250.59	0.79
Coal (Houchin Creek/Summum), normally bright-banded, strongly mineralized with sulfides at base and mid-level (samples macerations 3316A-G).	250.59	252.67	2.08
Claystone (underclay); gray, slickensides common, sulfides present, non-calcareous except weakly calcareous zone near top, top 0.12 foot is carbonaceous, sharp contact to coal. No core loss.	252.67	255.54	2.87
Claystone; slightly calcareous at base, more calcareous upward, better indurated than above unit. 1.00 foot drilling loss.	255.54	257.66	2.12
Coal, impure, not cleated; some sulfides.	257.66	257.71	0.05
Claystone (underclay); light gray to greenish gray, gray brown at top and bottom, weak, some slickensides, slightly silty, slightly calcareous in top half; top 0.05 foot is carbonaceous. No core loss.	257.71	259.33	1.62
Shale, medium gray, not visibly laminated but moderately fissile; shows sub-vertical secondary golden brown mineralization, with lesser amounts as separate 0.04 to 0.08-foot blebs; abrupt top contact with carbonaceous parting. No core loss.	259.33	265.92	6.59
Limestone, argillaceous; hard, massive, gray, odd granular texture, only slightly calcareous (dolomitic?). No core loss.	265.92	266.36	0.44
Shale, dark gray; not sideritic, laminated, poorly fissile, poorly indurated. No core loss.	266.36	266.91	0.55
Shale, dark gray, with scattered thick sideritic bands (0.05 to 0.22 foot); scattered small marine fossils in bottom 1.3 feet (brachiopods, crinoid fragments and unknown spines). Boundaries of sideritized zones cross bedding. The few plant fossils are wood-like material, not leaflets. Slickensides around sideritic nodule near top of unit. Loss 0.04 foot.	266.91	276.11	9.20

Shale, medium gray; plant debris common, faintly laminated, some bioturbation traces. Zone 0.20 foot thick at 0.65 foot down shows light brown mineralizations from sand to 0.03 foot in size. Small marcasite/pyrite lenses near base of unit. Gradational top contact. 0.02 foot loss.	276.11	280.61	4.50
Shale (Mecca Quarry), dark gray to black, fissile, non-calcareous; finely laminated throughout. First 0.02 foot above contact is coaly shale. Several slickensided planes found about 0.35 foot above base. Small brown calcareous nodules and thin bands seen in top 0.45 foot of unit appear to be calcite/phosphate bands. Gradational top contact. No losses.	280.61	282.17	1.56
Coal (Colchester), 0.05 foot coal at base, 0.08 foot pyritic claystone parting, then 0.75 foot coal at top. Coal below parting dull but cleated; normally bright-banded, cleated coal above. Sharp top contact. No losses (sample maceration 3317).	282.17	283.05	0.88
Siltstone, light gray to gray mottled, scattered slickensides, non-calcareous. Grades upward to coarse siltstone; carbonaceous fragments also increase upward in number. Faintly bedded, some non-horizontal carbonaceous laminae. Top 0.35 foot very carbonaceous, uppermost 0.2 foot is silt interlaminated with coal stringers. Sharp contact to coal above (no underclay). Loss of 0.22 foot from spinoff.	283.05	287.51	4.46
Sandstone, fine- to very fine-grained, tan to very light gray (tan from oil-staining) with coarse-grained mica common. Sand is subangular to subrounded, quartz dominated. Lower portion has common shale laminae, light gray; some slickensides. A few shale interbeds are up to 0.2 foot thick. Upper half shows apparent bioturbation; upper contact gradational. No core loss.	287.51	293.09	5.58
Shale, medium to dark gray, poorly bedded and indurated, some slickensides, slightly micaceous; local thin sandy intervals, similar to sands below. Non-calcareous. Bedding ranges from angular (30°) to wavy horizontal. Thin sideritized zones present. Angular top contact to sandstone; possible soil? mottling at top. No core loss.	293.09	300.23	7.14
Shale, very dark gray; scattered siderite nodules at base that grade upward to sideritized zones toward top of unit, otherwise non-calcareous. Scattered leaf and plant debris throughout, slickensided at top. No losses.	300.23	303.95	3.72
Interbedded sandstone and shale, bedding wavy to irregular. Micaceous sandstone has formed several small load structures on shale. Shale beds range from 0.08 foot to thin laminae. Scattered plant fragments. Lithologies similar to interbedded interval below. Upper contact is sharp, somewhat irregular. No core loss.	303.95	304.55	0.60
Shale, very dark gray, non-calcareous, coalified plant compressions and laminae common, subtle laminated bedding; sharp irregular upper contact. No core loss.	304.55	305.67	1.12
Interbedded shale and sandstone; shale is very dark gray, planar laminated to wavy laminated; non-calcareous, some mica; plant laminae and coalified compressions common. Contains a clear unconformity below a sandstone bed 0.1 foot thick. Sandstone is fine-grained, gray, similar to sandstone described below; bedding in upper half of unit is irregular. Loss of 0.04 foot.	305.67	307.34	1.67
Sandstone, medium-grained at base grading upward to fine-grained.Very permeable at base, moderately so at top. Grains are primarily subangular, some subrounded; moderate sorting at base; bedding difficult to see, but ranges from massive to laminated; scattered carbonaceous to coaly laminated zones, some at medium angles; bedding planes horizontal to 45°, suggesting local load structures; hole appears to have deviated about 10° through lower sandstone; angular unconformity at base. Losses total 0.08 foot.	307.34	335.41	28.07
MISSISSIPPIAN SYSTEM			
Siltstone (Borden), light greenish gray, laminated bedding dominates; angular top contact, bedding disruptions common, bioturbated intervals common, scattered rip-up clasts and small spotty sideritic-cemented zones, otherwise non-calcareous. Early diagenetic nodules (sideritic?) common in bottom 5 feet of unit; several have geode appearance with white coating. FeS (marcasite?) nodule near base; bioturbation very common in the bottom 10 feet of unit. Losses total 0.18 foot. Total depth is 367.06 feet.	335.41	367.06	31.65

Appendix 2

Core description A.E. Kleiss No. VGDH-2
Near center of NW, SW, NW, Sec. 30, T16N, R9E
Villa Grove Quadrangle, Douglas County
County No. 22743
Core No. 14845
Surface elevation 659 feet ETM

Logged by A. Hansel (Quaternary System), Z. Lasemi and D. P. Canavan (Pennsylvanian-Devonian Systems), and D. G. Mikulic and J. Kluessendorf (Silurian-Ordovician Systems).

	Depth below surface		
	Top (feet)	Bottom (feet)	Thickness (feet)
QUATERNARY SYSTEM			
Wisconsin Episode			
Lemont Formation			
Batestown Member			
Diamicton, silt loam; lower portion is calcareous; oxidized and brown (upper 8 feet) and unoxidized and dark gray/gray (8 to 10 feet).	0.0	10.0	10.0
Sand and gravel, with some clay lenses, calcareous; dark gray silty diamicton at 22.5 to 23 feet and 32.25 to 32.75 feet.	10.0	37.0	27.0
Tiskilwa Formation			
Diamicton, calcareous; silty; dark gray with reddish hue; abrupt lower contact.	37.0	38.0	1.0
Illinois Episode			
Glasford Formation			
Vandalia Formation			
Diamicton, with very poorly sorted sand layers; mildly calcareous; olive brown to very dark gray; more massive with depth.	38.0	43.0	5.0
Sand, fine; calcareous; oxidized.	43.0	45.5	2.5
Diamicton, silt loam; calcareous; dark gray; fairly massive; oxidized and grayer zones from 56 to 59 feet and very hard and massive.	45.5	59.0	13.5
Sand, calcareous. .	59.0	61.0	2.0
Pre-Illinois Episode			
Banner Formation			
Diamicton, silt loam; calcareous; dark gray with a reddish hue; very hard.	61.0	63.0	2.0
Sand, fine to coarse; poorly sorted, calcareous.	63.0	67.0	4.0
Diamicton, silt loam; calcareous dark gray; very hard.	67.0	87.0	20.0
Sand, fine to medium; calcareous.	87.0	89.5	2.5
Diamicton (accretion?), clay loam with few pebbles; mildly calcareous; dark gray to olive-gray.	89.5	93.0	3.5
Diamicton, loam; highly calcareous; dark gray to olive-gray; some sand and silt partings.	93.0	99.0	6.0
Diamicton, clay loam and very pebbly (2-cm diameter): calcareous; dark gray, but with faint color layers.	99.0	113.0	14.0
Diamicton (gleyed), clay loam but very variable; grayish green with pebbly bands, blue material is leached, distinct color layers of dusky red to olive-gray, dark gray at 120 feet; some coal at 119 feet.	113.0	121.5	8.5
Silt (colluvial or accretionary) with fine sand layers beginning at 124.5 feet; leached; dark gray to black; organics; gastropods at 124 feet; more organics at 124.5 feet; more pebbles near base.	121.5	127.0	5.5

Diamicton, silty clay loam with pebbles; leached; thin organic layer at 128.5 feet.	127.0	133.0	6.0
Silty clay, dark gray to dark; olive-gray silty; clay loam (accretionary?); leached.	133.0	133.7	0.7
Diamicton, silty clay; dark gray; gleyed, mottled, and few pebbles at 137 feet; leached to mildly calcareous.	133.7	137.5	3.8
Silt, leached; olive-gray with oxidized blue colors; laminated.	137.5	143.0	5.5

PENNSYLVANIAN SYSTEM

Conglomerate with clasts of various sizes, shapes, and colors, in a rusty red matrix. Clast types include dolomite, chert, siltstone, etc.	143.0	143.8	0.8

DEVONIAN SYSTEM

Upper Devonian Series

New Albany Shale

Shale, medium gray and chocolate brown, weathered olive-gray in upper part.	143.8	146.9	3.1
Shale, greenish gray interbedded and mottled with light olive-gray.	146.9	150.9	4.0
Shale, medium brown with mottling and laminations of greenish gray. Pyritic to very pyritic at base.	150.9	151.2	0.3

Sylamore Sandstone

Sandstone, medium dark gray, argillaceous, pyritic with pyritic clasts 0.5 inch to 1 inch across just below contact at base. Basal contact undulatory.	151.2	151.4	0.2

Middle Devonian Series

Lingle (St. Laurent) Formation

Dolomite, medium-light brownish gray to light brownish gray, fine to medium crystalline, dense with some fossil moldic porosity. Slightly cherty to cherty (up to 2 inches across), very light gray. From 156.5 to 157.8 feet, very fossil moldic (mostly small vugs with rare large vugs). Slightly oil-stained. Slightly fossiliferrous.	151.4	157.8	6.4
Dolomite, medium light gray with light olive-gray tinge, fine to very finely crystalline, dense. In part burrow mottled (light gray), looks argillaceous with common wispy laminations. Very cherty to cherty, very light yellow gray. Rare vugs, in part laminated.	157.8	164.5	8.7
Dolomite, fine to medium crystalline, upper 2 feet is light brownish gray with a light olive tinge, the rest is medium light gray, fossil moldic and vuggy (upper 2 feet is less vuggy). Abundant bryozoans and some echinoderms; some vertical healed fractures.	164.5	168.5	4.0
Dolomite, medium gray, yellow-brown to gray-brown, mostly oil-stained dark brown, fine to coarse crystalline, slightly to very vuggy. Very fossiliferrous with common well-preserved corals and possible stromotaporoids. Other recognizable fossils are echinoderms, bryozoans, and brachiopods; interbedded with some argillaceous, silty, calcareous dolomite.	168.5	178.2	9.7
Limestone (wackestone), very fine- to fine-grained, dense, medium-light gray to light olive-gray. Scattered fossil fragments (echinoderms and brachiopods); slightly cherty to cherty (very light gray). 0.5 feet at base is intraclastic with coarse fossil fragments.	178.2	184.1	5.9
Limestone (crinoidal grainstone), medium-grained (in part very fine), dense, gray brown. Top contact is a discontinuity surface with 1.5 inches to 2 inches relief with intraclasts (some dark gray) above the contact.	184.1	187.7	3.6
Limestone (packstone to grainstone), fine- to medium-grained, light to medium gray to light brownish gray to brownish gray. Scattered coarse to very coarse fossil fragments; several wispy laminated zones; top 0.5 inch contains abundant very coarse echinoderm fragments with numerous shale partings.	187.7	190.7	3.0
Limestone (grainstone), fine- to medium-grained (well sorted), visible porosity, tan brown with a yellow tinge. Slightly dolomitic, abundant small porosity; fossils are crinoid and bryozoan. Shale partings near base; basal 2 feet has scattered large corals and stromotaporoids and some black grains.	190.7	193.8	3.1
Limestone (lime mudstone with 2 inches of wackestone at base), scattered corals, light to very light gray brown allochems with dark brown shaley matrix. Dominated by corals and scattered stromotaporoids; numerous wispy laminations, highly compacted.	193.8	194.9	1.1

Limestone (grainstone) as 190.7 to 193.8 feet. Large hexagenarian coral (2.5 inches across) at upper 0.4 feet, also scattered small corals; base is undulatory with a concentration of echinoderm fragments.	194.9	195.5	0.6
Limestone (wackestone), fine- to medium-grained, dense, light gray-brown with an olive tinge at top to dark gray-brown at bottom. Slightly dolomitic; top 0.1 foot is micrite, appears laminated; floating echinoderm fragments; dark gray shale parting separates top and bottom units.	195.5	196.0	0.5
Limestone (interbedded and mottled grainstone and lime mudstone), fine- grained, dense, medium blue-gray with medium brown to blue-gray mottling. Lower 0.6 foot is mostly grainstone (light gray brown); from the top to 197.5 feet is dolomitic (heavily mottled).	196.0	198.7	2.7
Limestone (lime mudstone with some thin interbeds of wackestone to packstone), fine-grained, dense, light gray to light gray brown. Top contact is a minor discontinuity surface—pyritic, blackened surface, intraclastic. Several major shale partings (compacted nodular zones) with numerous green/gray wispy laminations.	198.7	202.4	3.7
Limestone (boundstone with wackestone matrix), allochems are fine to 0.5 foot across, dense, brown to gray-brown. Scattered floating corals, common stromotaporoids and echinoderms throughout; scattered dark gray specks and mottling; in part pyritic near base.	202.4	204.2	1.8
Limestone (lime mudstone, wackestone, and packstone), dense. Rudstone: 204.2 to 205.7 feet, light gray to light gray-brown, coral-dominated (up to 3 inches across, mixture of solitary and colonial), dark brown, argillaceous, wispy laminations. Wackestone at 205.7 to 206.5 feet, light brownish gray to brownish gray, slightly argillaceous. Wackestone to packstone: brown to brownish gray, slightly dolomitic, scattered floating small to large corals and other unidentifiable fossils.	204.2	207.5	3.3
Limestone (lime mudstone), dense, medium brown to medium gray-brown. From 207.5 to 209.5 feet is clean mudstone with rare mottling, minor argillaceous partings, and thin vertical fractures near top. The rest is very cherty, blue-gray, irregular with light gray halos (up to 1 mm) (possibly burrows?), slightly dolomitic?.	207.5	211.5	4.0
Limestone (grainstone to packstone), fine- to coarse-grained, dense, dark gray-brown with light gray allochems. Several shale partings at top; echinoderms and minor brachiopods; dark gray allochems, possibly siliceous. Base is sharp contact with next unit.	211.5	212.2	0.7
Shale, dark gray with very small to 0.5-inch limestone and dolomite intraclasts, dark gray. Top is 1.25 inches of shale over very argillaceous, dark gray brown dolomite (disconformity.)	212.2	212.5	0.3
Grand Tower Formation			
Dolomite, microcrystalline, light gray-tan. Some blue-gray mottling; upper part and several zones throughout are heavily brecciated; rare argillaceous partings in lower part. Argillaceous and sandy at 217.5 feet.	212.5	218.2	5.7
Dolomite, fine to medium crystalline, in part fenestral, light tan. Some possible fossil moldic porosity, oil stains intermittent.	218.2	223.0	4.8
Dolomite, mostly microcrystalline with some medium crystalline, variable porosity from vuggy to dense (mostly with little or no visible porosity). Lower 3 feet or so is slightly sandy. Some very light blue-gray laminar mottling, abundant domal stromatolitic laminations; two brownish gray to light gray-brown sandy argillaceous beds up to 1 inch thick in lower 5 feet.	223.0	238.0	15.0
Bentonite, light gray-green **(“Tioga” Bentonite Bed)**	238.0	238.2	0.2
Dolomite, light yellow-brown to light brown, pinpoint porosity with some vugs, sandy (arenaceous) to very sandy in some places; sandy to sandstone horizons at 240 and 243.5 feet. Sand is medium- to coarse- grained, subrounded. Siltstone bed, <0.1 foot thick at 244.2 feet, soapy, dark gray to light olive-gray-brown. Some oil stains throughout; lower foot is very sandy; faint laminations in some intervals.	238.2	247.1	8.9
Dolomite, light blue-gray to medium gray to light yellow-brown to tan-white, vuggy, fenestral, and burrow porosity. Still sandy to very sandy in some areas; more porous and stained than unit above. Brecciated layers with small white clasts at 252.3 and 253.5 feet; good laminations; fenestral fabric is prominent.	247.1	256.5	9.4

Dolomite, chalky white to medium tan, fine- to very fine- to microcrystalline, dense to pinpoint porosity to rare vugs, interbedded with chalky, microcrystalline dolomite; prominent chalky layers at 267.1 to 268 feet and basal 3.5 feet. From 258 to 258.5 feet is intraclastic; argillaceous partings (wispy laminations/stylolites) at 258.5 feet and 265.7 to 265.9 feet, partings are dark gray to olive-gray; distinctive dark gray layer at 258.6 feet (shale); rare vertical fractures; possible stromatolitic laminations in dolomite; allochems are echinoderms and brachiopods.	256.5	273.7	17.2
Shale, medium dark gray with olive tinge, finely laminated, calcareous.	273.7	273.9	0.2
Dolomite, dense, light blue-gray to light olive-tan to light gray. Denser and not as pure white as unit above. Intraclastic? porous unit from 274.8 to 275 feet; small, white clasts from 273.9 to 274.8 feet; similar to chalky unit above; argillaceous at base.	273.9	275.5	1.6
Dolomite, very fine to microcrystalline, moderately vuggy, medium brown to yellow brown to medium gray brown. Argillaceous zones; sandy from 277.5 feet to base.	275.5	278.0	2.5
Dolomite, medium to microcrystalline, common vuggyness with rare pinpoint to pin-head porosity, tan to medium gray. Interbeds and mottling of blue-gray dolomite (possibly argillaceous); some areas distorted and look brecciated; vertical to semi-vertical healed fractures in some intervals; 299.3 to 299.9 feet is a prominent white layer; very sandy interval at 294.0 to 296.5 feet (with small white clasts) and at 301.0 to 303.5 feet; very sandy to medium-grained dolomitic sandstone at base.	278.0	311.3	33.3
Dolomite, medium crystalline, fenestral and vuggy porosity, medium to dark blue-gray with a tan tinge.	311.3	315.7	4.4
Dolomite, fine to medium crystalline, dense, buff with some blue-gray streaks (Dutch Creek Sandstone equivalent); major stylolite approximately 1 foot above base.	315.7	317.6	1.9
Lower Devonian Series			
“unnamed biohermal unit”			
Dolomite, medium to coarse, buff tan, slightly vuggy.	317.6	319.2	1.6
Dolomite, fine to coarse crystalline, very vuggy and fossil moldic porosity, medium gray-brown. Grades from 318 feet into this unit; 326.4 to 327.3 feet is less vuggy, denser with shale partings at top and at base; oil-stained sporadically; common coral molds.	319.2	332.0	12.8
Dolomite, blue-gray interbedded and mottled with buff-gray-brown. Much cleaner than above with some scattered vugs; common wispy laminations/argillaceous beds and partings especially in upper 5 feet; approximately 0.25-inch thick shale at 337.6 feet; basal 1.7 feet is clearly brecciated with heavy oil stains	332.0	339.8	7.8
SILURIAN SYSTEM			
“unnamed cherty unit”			
Dolomite, very finely crystalline to slightly argillaceous, light olive-gray with light orangish brown mottling, massive, with common chert nodules after burrows; uncommon biomoldic porosity.	339.8	393.0	53.2
Moccasin Springs Formation			
Dolomite, fine to medium crystalline, pale brown, highly porous, with abundant fine to medium biomoldic porosity, especially pelmatozoan bioclasts. From 441.2 to 460.5 feet, the pale brown lithology interbeds with thin beds of light gray, finely crystalline dolomite, with occurrence of argillaceous partings. Reef or carbonate bank lithology.	393.0	471.0	78.0
Dolomite, light to dark gray, fine crystalline, massive, containing common to abundant bio-moldic porosity, especially pelmatozoans, which commonly form grainstones; bryozoans are also fairly common. Common stylolites. Thick greenish-gray argillaceous parting at base. Some of the biomoldic porosity filled with oil. Reef or carbonate bank lithology.	471.0	527.4	56.4
Dolomite, slightly argillaceous, light olive-gray to greenish gray, with common small, crystal-lined vugs.	527.4	533.8	6.4
Shale, very dolomitic to argillaceous dolomite, greenish gray to light olive-gray, containing zones of silicified pelmatozoan and scattered other silicified bioclasts, including tabulate and rugose corals. From 547.5 to 567.2 feet are thin burrow zones in more argillaceous intervals.	533.8	609.0	75.2

Dolomite, thicker layers of argillaceous dolomite to dolomitic shale, typically with silicified bioclasts (skeletal wackestone, packstone and grainstone) interbedded with thinner layers of more crystalline, light olive-gray dolomite that contain common fine biomoldic porosity and dark gray chert nodules.	609.0	690.0	81.0
Dolomite, very fine crystalline, very light gray, dense, nonporous with argillaceous partings and intervals of fenestrate bryozoan and pelmatozoan bafflestone interbedded with dark greenish gray dolomitic shale.	690.0	763.0	73.0
St. Clair Limestone			
Limestone, pink to red or very light gray with common to abundant pelmatozoan bioclasts (packstone to grainstone) interbedded with pinkish gray, greenish gray, or light gray lime mudstone. Greenish gray or reddish brown argillaceous partings are common, becoming abundant at the top. Contact with underlying Sexton Creek is sharp, irregular, corroded, and pitted.	763.0	900.3	137.3
Seventy-Six Shale			
Limestone (lime mudstone), dolomitic, dominantly light gray to very light brownish gray, but pinkish gray at top, dense, nonporous, even-textured. Several “hardgrounds” from 901.1 to 901.6 feet. More argillaceous in lower 3 feet. Compacted, Thalassinoides burrows filled with argillaceous material near bottom.	900.3	905.5	5.2
Sexton Creek Formation			
Dolomite, fine to coarse crystalline, dark brownish gray, nonporous, faintly mottled, bioturbated, with common dark brownish black argillaceous partings. Chert nodules appear from 908.7 to 912.4 feet. Bioclasts, including brachiopods and pelmatozoans occur in chert and matrix (skeletal wackestone to grainstone) in basal 0.5 foot	905.5	917.7	12.2
Dolomite, gray, crinkly algal laminite with several thin zones of phosphatic clasts. Basal 1 foot is planar-laminated, dark brown, dolomitic mudstone. Greenish gray shale clasts at base.	917.7	920.5	2.8
ORDOVICIAN SYSTEM			
Maquoketa Group			
Shale, dark greenish-gray; interbedded with tan, nonporous, dense, even-textured dolomite bands down to 977.8 feet.	920.5	1,007.9	87.4
Limestone, light gray, fossiliferous, with thin greenish gray shale interbeds in lower 10 feet.	1,007.9	1,037.2	29.3

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF ILLINOIS
DEPARTMENT OF ENERGY AND NATURAL RESOURCES
GEOLOGICAL SURVEY DIVISION
CHAMPAIGN, ILLINOIS

VILLA GROVE QUADRANGLE
ILLINOIS–DOUGLAS CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY ... USGS AND NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN ... 1980
FIELD CHECKED ... 1981 MAP EDITED ... 1982
PROJECTION ... TRANSVERSE MERCATOR
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR ... ZONE 16
10,000-FOOT STATE GRID TICKS ... ILLINOIS, EAST ZONE
UTM GRID DECLINATION ... [illegible] WEST
1982 MAGNETIC NORTH DECLINATION ... [illegible] EAST
VERTICAL DATUM ... NATIONAL GEODETIC VERTICAL DATUM OF 1929
HORIZONTAL DATUM ... 1927 NORTH AMERICAN DATUM
To place on the predicted North American Datum of 1983 move the projection lines as shown by dashed corner ticks (1 meter south and 4 meters east)
There may be private inholdings within the boundaries of any Federal and State reservations shown on this map
Gray tint indicates areas in which selected buildings are shown

PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of field check.

SCALE 1:24 000

KILOMETERS
METERS
MILES
FEET

CONTOUR INTERVAL 1.5 METERS

CONTROL ELEVATIONS SHOWN TO THE NEAREST 0.1 METER
OTHER ELEVATIONS SHOWN TO THE NEAREST 0.5 METER
To convert meters to feet multiply by 3.2808
To convert feet to meters multiply by .3048

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092
AND THE STATE GEOLOGICAL SURVEY, CHAMPAIGN, ILLINOIS 61820

QUADRANGLE LOCATION

1	2	3	1 Tolono 2 Villa Grove NW 3 Longview 4 Tuscola 5 Murdock 6 Arcola 7 Hindsboro 8 Oakland
4		5	
6	7	8	

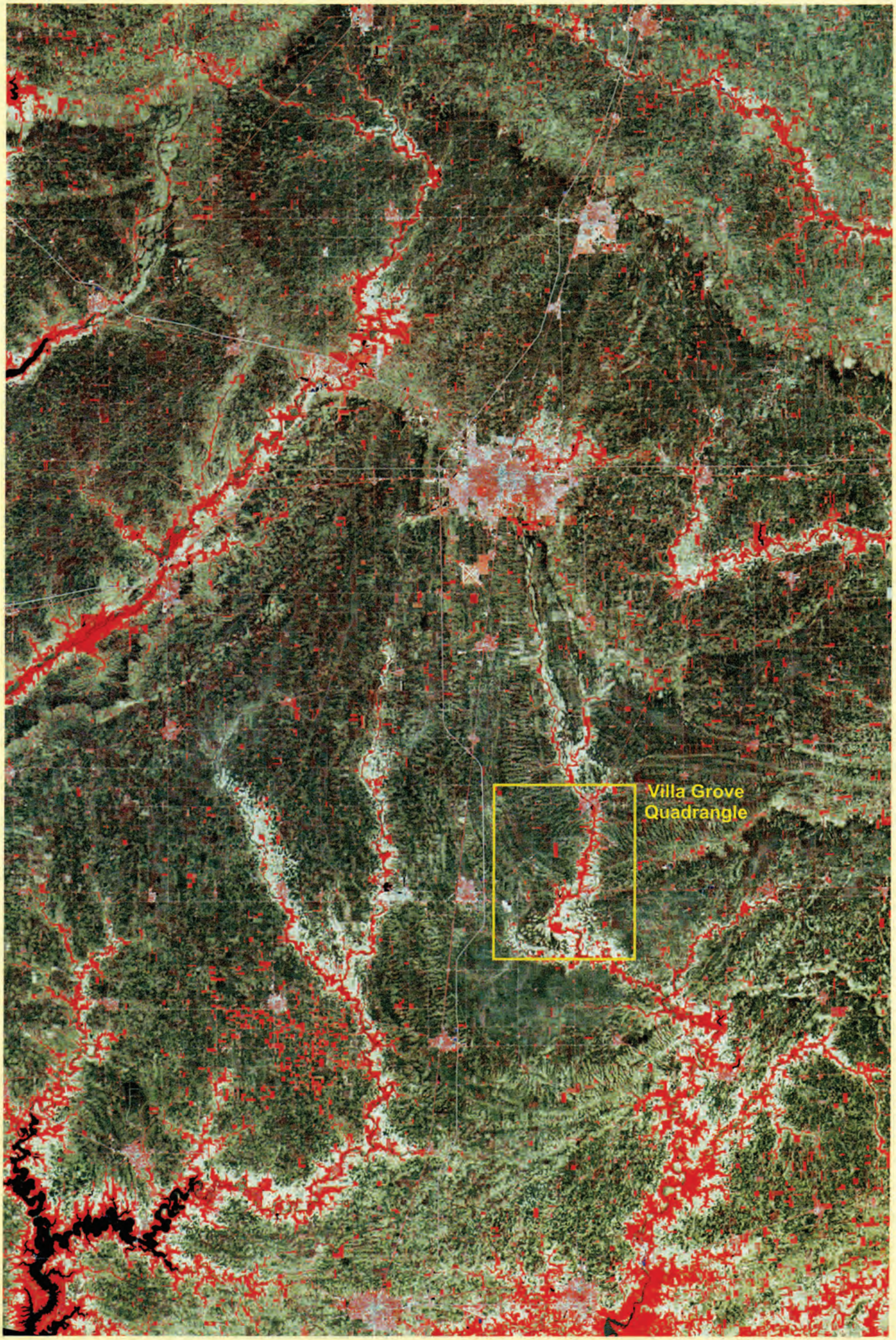
ADJOINING 7.5' QUADRANGLE NAMES
CONTOURS AND ELEVATIONS
IN METERS

ROAD LEGEND

Improved Road
Unimproved Road
Trail

Interstate Route U. S. Route State Route

VILLA GROVE, ILLINOIS
PROVISIONAL EDITION 1982
39088-G2-TM-024


Villa Grove
Quadrangle