KARST REGIONS OF ILLINOIS

Open File Series 1997-2

S.V. Panno, C.P. Weibel, and W. Li

Illinois State Geological Survey

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ABSTRACT

Karst occurs in Illinois where bedrock exposures and subcrops consist of carbonate rocks. Approximately 25% of Illinois' bedrock is carbonate rock, and of that area, approximately 35% (equals 9% of the state) includes the state's five karst regions. The highest degree of karstification occurs in southwest and southern Illinois where the Mississippian limestones are predominant. Karst encountered in Illinois, as classified by their dominant landforms, included sinkhole karst, cave karst, and pseudo-sinkhole and pseudo-cave karst that resulted from human modifications to the land. Only natural karst terrains are studied herein, and only the most karstified areas are described in detail.

The carbonate bedrock of Illinois was the focus of our efforts because these rocks are susceptible to karst development. Carbonate bedrock is either exposed at land surface or covered by relatively thin glacial till (diamicton), loess, and other unlithified sediment around the margins of the Illinois Basin, and along the flanks of structures within the basin. Karstic features are concentrated in five regions: (1) the Driftless Area of northwest Illinois, (2) north-central Illinois, (3) the Lincoln Hills of the western Illinois, (3) the Salem Plateau of southwest Illinois, and (5) the Shawnee Hills of southern Illinois. A few caves and sinkholes occur in northeastern Illinois, and in La Salle and Douglas Counties in carbonate rocks associated with either the LaSalle Anticlinorium or the northeast flank of the Illinois Basin (Kankakee Arch).

INTRODUCTION

Background

Carbonate rock comprises approximately 25% of the bedrock surface in Illinois. Of the area underlain by carbonate rocks, 35% of that area (equals 9% of the state) is included in the five regions that contain evidence of numerous karstic features at the land surface. The term "karst" is defined by Ford and Williams (1989) as "...terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well developed secondary porosity." Features that typify karst terrain include closed depressions (sinkholes), caves, large springs, fluted rock outcrops (Ford and Williams, 1989), blind valleys and swallow holes (White, 1988).

Carbonate rocks generally have low primary porosity and permeability; however, secondary porosity (fractures) permits the rapid transport of large volumes of water into and through the rock. The movement of surface waters (rainwater and snowmelt), through soil, and into fractures in soluble carbonate bedrock is responsible for the development of karst terrains. Because of the microbial generation of carbon dioxide in the soils overlying carbonate rock, infiltrating water becomes acidic prior to entering fractures, joints and bedding planes in carbonate rocks. Small amounts of calcite and/or dolomite (the dominant minerals in carbonate rock) dissolve in accordance with the following simplified reactions:

$$\text{Calcite: } CaCO_3 + H^+ \leftrightarrow Ca^{2+} + HCO_3^-$$

$$\text{Dolomite: } CaMg(CO_3)_2 + 2H^+ \leftrightarrow Ca^{2+} + Mg^{+2} + 2HCO_3^-$$

until the water approaches saturation with respect to the solubility of these mineral phases (White, 1988). The slow dissolution of carbonate minerals over thousands to hundreds of

thousands of years gradually enlarges joints, fractures, and pathways along bedding planes through which water moves. Some pathways become large conduits or caverns through which groundwater flows to points of discharge (e.g., springs). Continued enlargement of the conduits eventually can result in the collapse of overlying rock and soil. Surface erosion eventually results in fragmentation and finally, destruction of the conduit system (White, 1988).

The relatively large interconnected pores present in fissured or karstified carbonate rock allow rapid movement of water into and through the rock bodies. These rock bodies often constitute locally important aquifers in Illinois; however, fissured and karst aquifers are very susceptible to surface-derived contamination. Recharge to karst aquifers often is rapid (analogous to water movement to drainage tiles) and carries with it materials (often macroscopic) from the land surface that include human and animal wastes, pesticides, urban runoff, and other waste products associated with the human culture of a region. In contrast, recharge to non-karst aquifers typically undergoes a slow migration through materials (e.g., thick, clay-rich glacial diamicton) that generally provide sufficient time and environment for chemical, biological, and physical degradation and retardation of pollutants. Unfortunately, residents who draw groundwater from karst aquifers for domestic use risk ingesting contaminants. Rare and endangered species that inhabit underlying caves are also at risk from chemical and bacterial contamination in groundwater. In addition, knowing where karst terrain is present in Illinois is important when conducting regional geological screening for citing facilities such as waste disposal sites and low-level nuclear waste repositories. Thus, it is important to identify the locations of karst terrain in the state for water-resource protection and regulatory purposes.

Purpose

The purpose of this investigation was to prepare a state-wide map and detailed maps of the karst terrains of Illinois and to describe the geologic and hydrogeologic controls of karstification. The detailed karst maps presented herein were prepared from a smaller-scale map of the state of Illinois (Weibel and Panno, in press) (Figure 1).

METHODOLOGY

Karst Maps

Karst maps were constructed for the state on the basis of landforms observed on 7.5-minute (1:24,000) topographic maps and stereo pairs of U.S. Department of Agriculture aerial photographs (1:20,000), bedrock lithology, cave locations, and sinkholes indicated on Natural Resources Conservation Service (formerly the Soil Conservation Service) county soil survey maps. Areas mapped as karst were field checked by the authors. As discussed above, carbonate bedrock is most susceptible to dissolution, particularly where it occurs at or near the land surface. The occurrence of caves in an area was used as an indicator of karst terrain. A map of the caves of Illinois found in carbonate rock was constructed using a confidential inventory of 313 caves (compiled by J.E. Gardner of the Illinois State Natural History Survey from his work and from a data base prepared by the Illinois State Museum). The term "cave" is defined as "any natural cavity or series of cavities beneath the surface of the earth. Such cavities are usually classified as caves only if they are large enough to permit entrance by humans" (Mohr and Polson, 1966). A literature search also was conducted for karstic features observed within the state and neighboring states. Karst regions were delineated on the basis of the location of indicator sinkholes, caves, and carbonate rock, without regard for the thickness and nature of Quaternary overburden. Because all carbonate

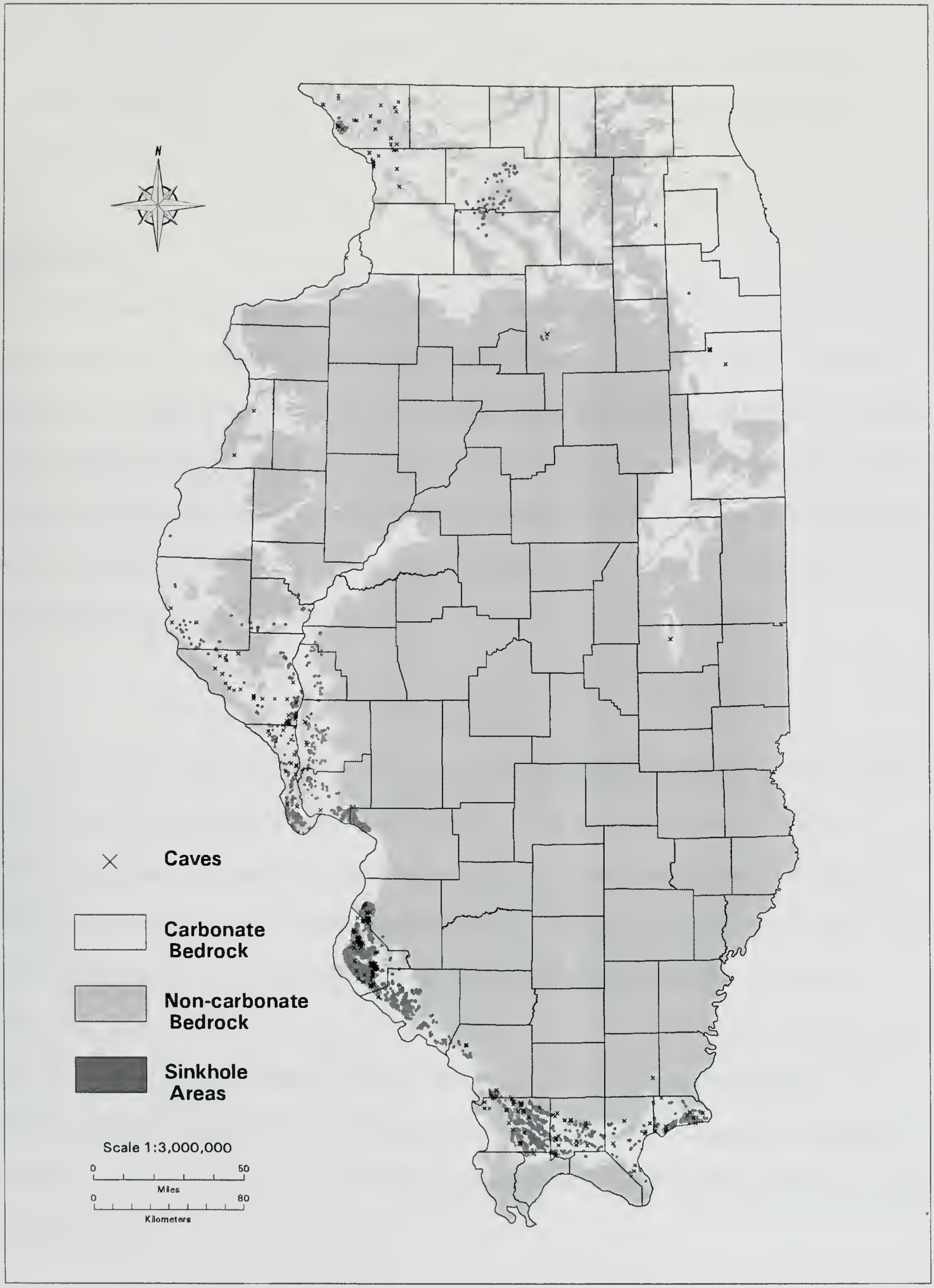


Figure 1. Map of the bedrock geology of Illinois showing sinkholes and caves (modified from Weibel and Panno, in press).

rock in the state shows some degree of dissolution (usually along joints and bedding planes), no area is described as "karst" unless it was identified as having a karst aquifer with associated karstic features.

Cross Sections

Cross sections of the areas containing carbonate bedrock and karstic features (Figure 2) were constructed to examine relationships between bedrock formations and karstification. The cross sections are schematic and were based on the following: 1) well records available at the Geological Records Library of the Illinois State Geological Survey (ISGS), 2) published references describing the geology of the surficial sediment, bedrock surface and subsurface, and 3) unpublished cross sections from the ISGS Map Library. Formation codes used in the cross sections are explained in Figure 3.

DISCUSSION

The focus of this investigation is on the carbonate bedrock of Illinois because these are the rocks most susceptible to karstic development. These rocks are either exposed or subcrop at the bedrock surface beneath glacial deposits around the margins of the Illinois Basin on the flanks of the Kankakee, Mississippi River, Pascola, and Wisconsin Arches, and the Ozark Dome, and, within the Illinois Basin, on the crest of the LaSalle Anticlinorium in east-central Illinois (Figure 2). Karstic features are concentrated in north-central Illinois, the Driftless Area, the Lincoln Hills, the Salem Plateau, and the Shawnee Hills (Figures 1, 2). Sinkholes and caves found in Kane, Kankakee, La Salle, and Douglas Counties are rare and generally isolated, and occur in carbonate rocks associated with the LaSalle Anticlinorium and Kankakee Arch.

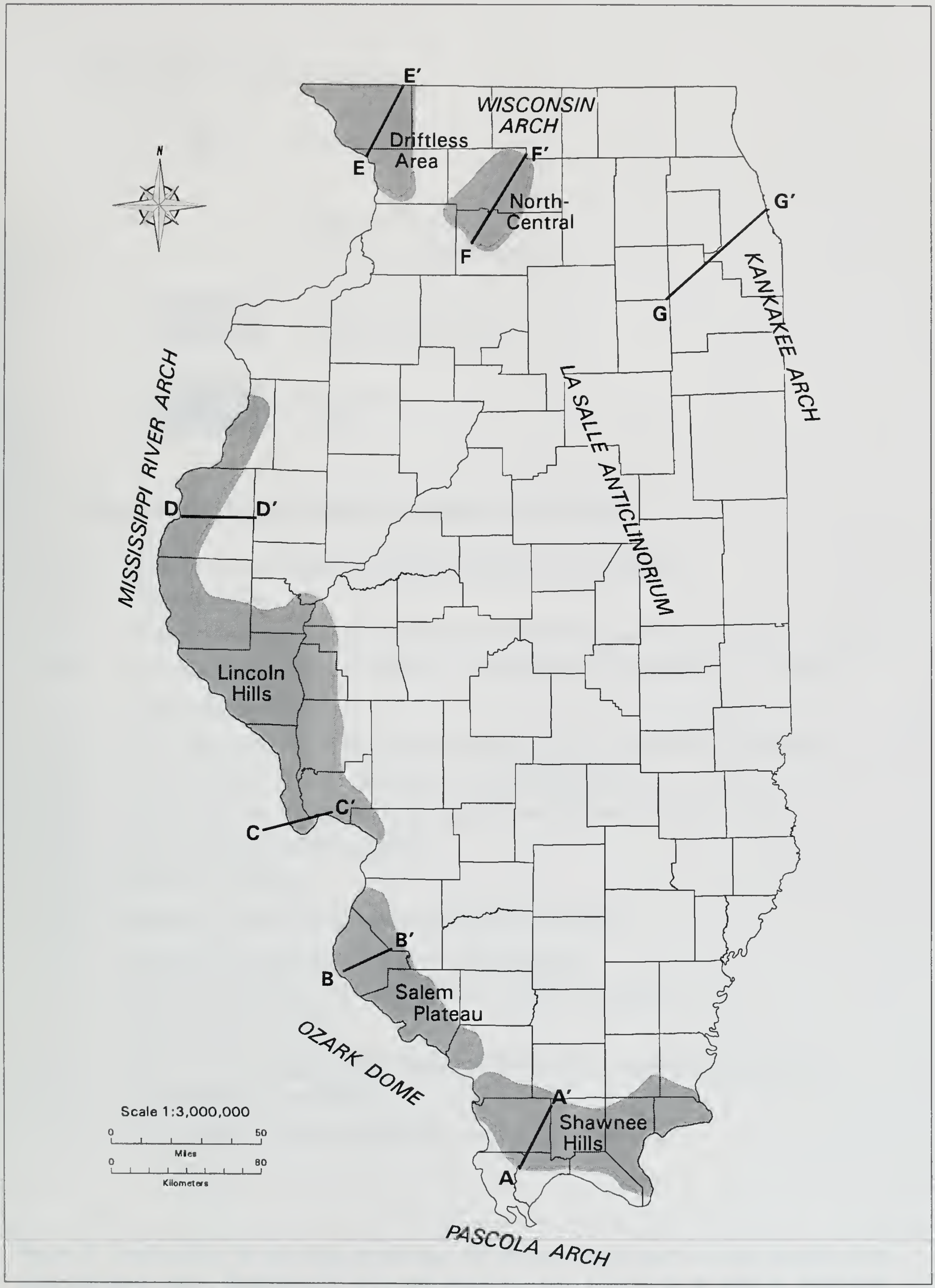


Figure 2. Map showing locations of cross-sections, karst regions, and major structures (in italics) of the Illinois Basin.

REGIONAL KARST MAPS

Caves

Predominantly Noncarbonate Bedrock

Predominantly Carbonate Bedrock

Sinkhole Areas

REGIONAL MAPS AND CROSS-SECTIONS

Q-P	=	Quaternary, consisting mostly of Pleistocene deposits
Penn	=	Pennsylvanian
Mcu	=	Mississippian, upper Chesterian (includes Vienna, Menard, Clore, Kinkaid)
Mcl	=	Mississippian, lower Chesterian (includes Renault, Ridenhower, Beech Creek, Glen Dean)
Mvu	=	Mississippian, upper Valmeyeran (includes St. Louis, Ste. Genevieve)
Mvm	=	Mississippian, middle Valmeyeran (includes Salem)
Mvl	=	Mississippian, lower Valmeyeran (includes Burlington, Keokuk)
Mk	=	Mississippian, Kinderhookian
Du	=	Devonian, Upper
Dm	=	Devonian, Middle (includes Grand Tower, Lingle)
Dl	=	Devonian, Lower(includes Bailey, Backbone)
S	=	Silurian (includes Kankakee, Sexton Creek, Hopkinton)
Ou	=	Ordovician, Upper
Om	=	Ordovician, upper Middle (includes Platteville, Galena, Kimmswick)
Oma	=	Ordovician, lower Middle
Ol	=	Ordovician, Lower (includes Shakopee)
C	=	Cambrian

Figure 3. Explanation for symbols, shadings, and abbreviations used in cross sections and regional karst maps. Stratigraphic units are modified from Willman et al. (1967). Relevant stratigraphic units mentioned in the text are contained within parentheses.

In the Illinois Basin, only Paleozoic-age rocks contain carbonate strata, whereas younger Mesozoic and Cenozoic rocks lack carbonate strata. Rock units that are karstified include (from oldest to youngest) limestones and dolomites of the Lower and Middle Ordovician and of the Silurian Alexandrian and Niagaran Series, limestone of the Lower and Middle Devonian Series, limestones of the Mississippian Valmeyeran and Chesterian Series, and the LaSalle Limestone of the Pennsylvanian Missourian Series (Figure 4). The most intensely karstified limestones occur within the Mississippian-age strata. The regions that contain numerous karstic features (particularly caves and sinkholes) are described in detail below. The geology and hydrogeology of each region are also discussed and formations that have undergone karstic development are described. Formation codes, symbols, and shadings used on the regional maps are explained in Figure 3.

Shawnee Hills Karst Region

Sinkholes and caves are abundant in the karst of the Shawnee Hills of southern Illinois. The Shawnee Hills karst region (Figures 2, 5, 6, 7) includes Jackson, Union, Johnson, Pope, Saline and Hardin Counties. A few sinkholes and caves are associated with the Lower Devonian Bailey and Backbone Limestones and Middle Devonian Grand Tower and Lingle Limestones in the west part of the Shawnee Hills. Most sinkholes and caves occur in soil overlying and within Mississippian Valmeyeran and Chesterian rocks (Figure 8A). Sinkholes are common to abundant in areas where bedrock is dominated by the Salem, St. Louis, Ste. Genevieve, Glen Dean, and Menard Limestones, and are found throughout most of the Shawnee Hills. Sinkholes also are commonly associated with the Haney Limestone Member of the Golconda Formation and the Kinkaid Limestone in the west part of the region. Karstic features are relatively rare in the Renault Limestone, Downeys Bluff Limestone Member of the

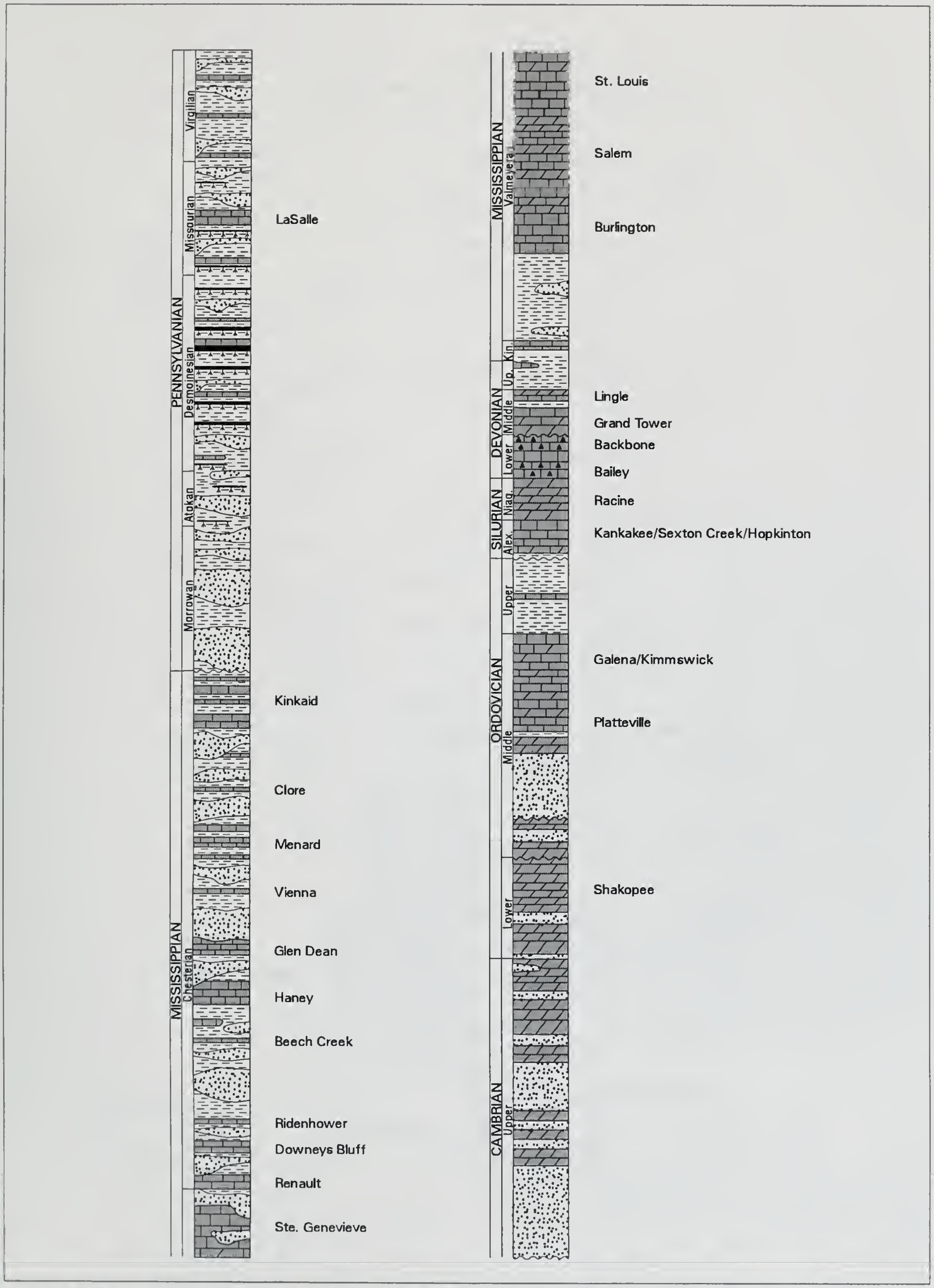


Figure 4. Generalized stratigraphic column of Paleozoic strata in Illinois, modified from Bell et al.(1961). Carbonate units are shaded gray. Known karstification zones are indicated by the stratigraphic names to the right of the columns.

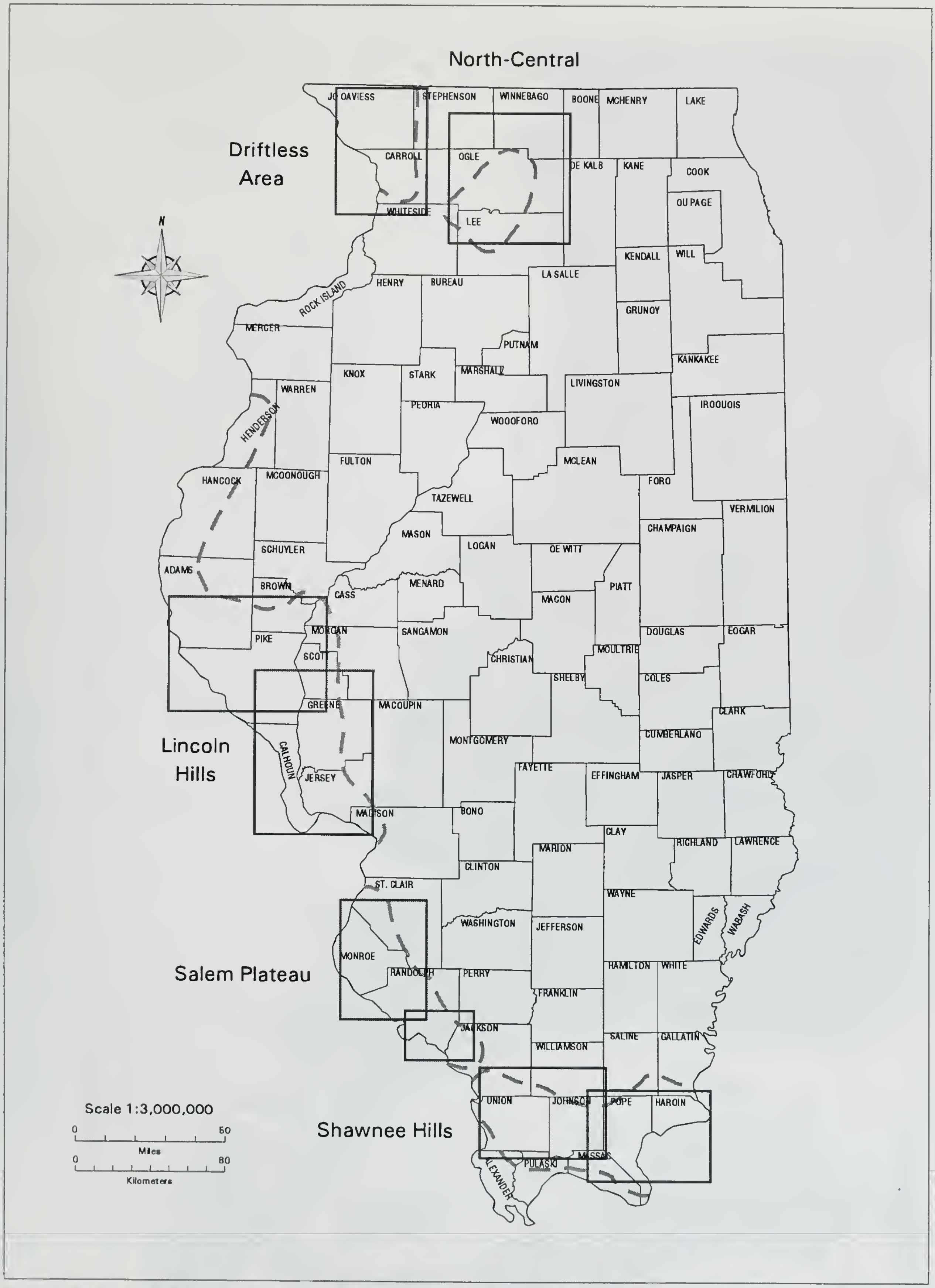


Figure 5. Index of regional karst maps, outlined by boxes. Dashed lines indicate extent of karst regions.

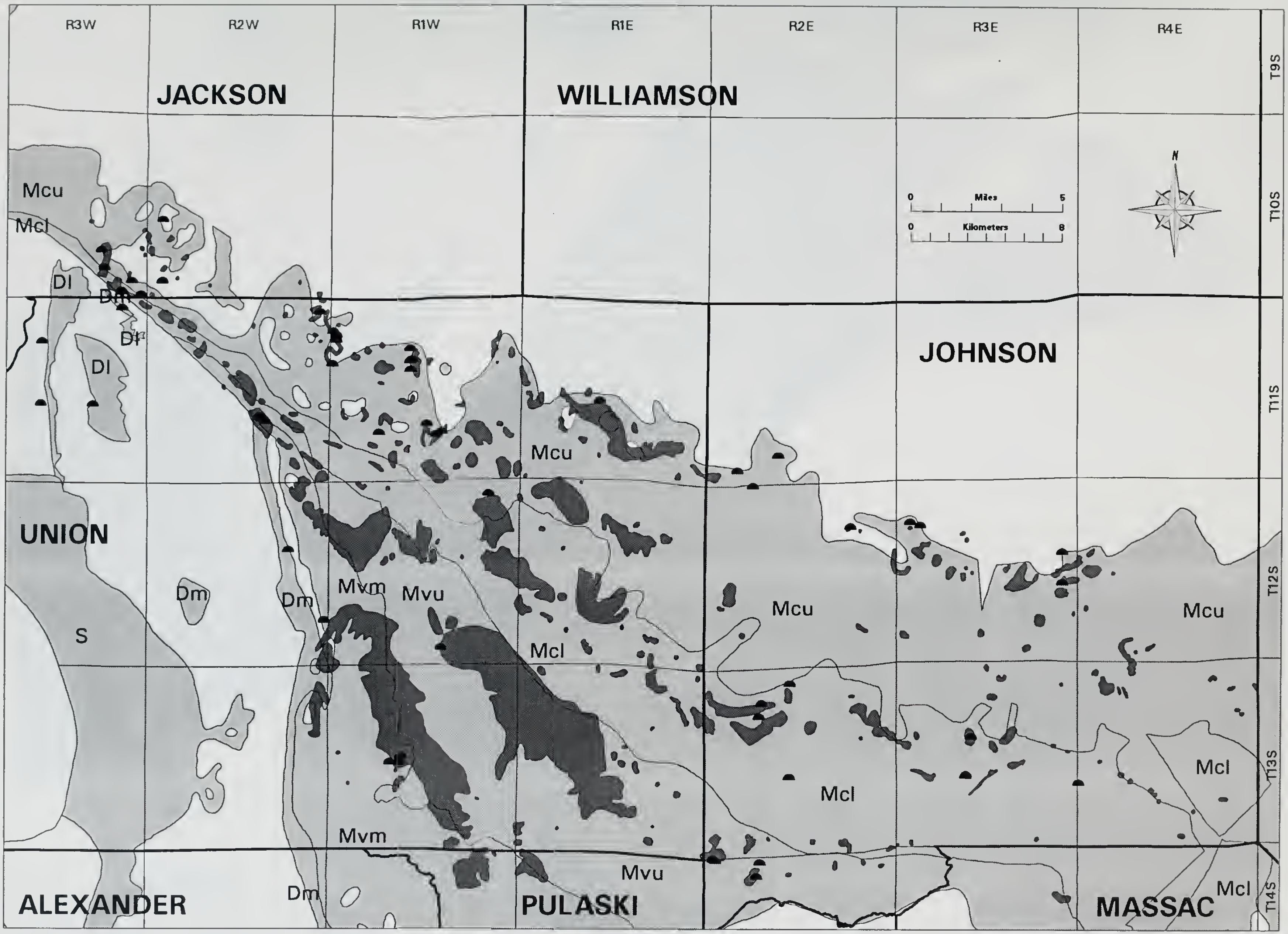


Figure 6. Karst map for the west part of the Shawnee Hills karst region. Geology modifed from Willman et al. (1967) and Devera (1993).

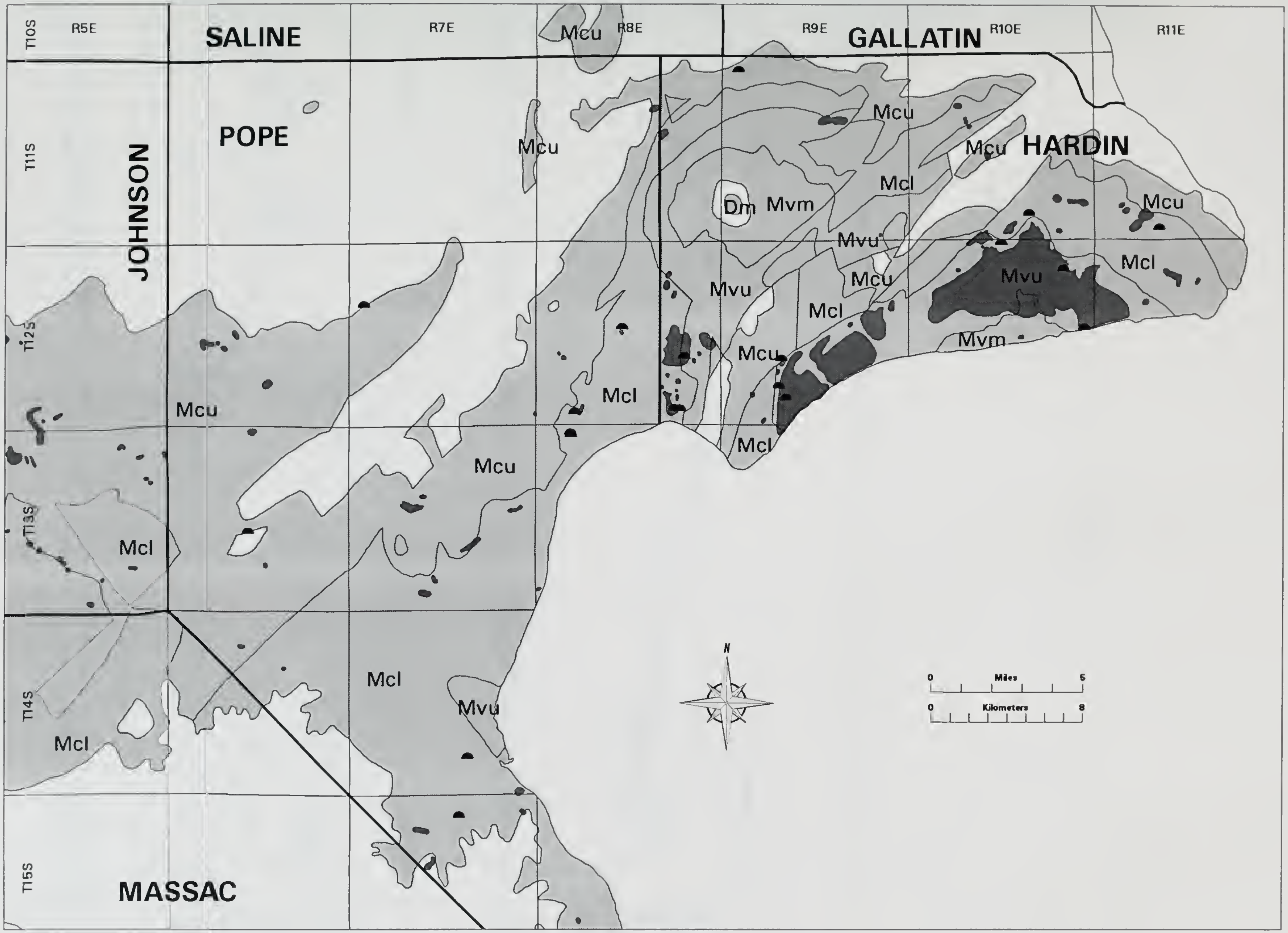
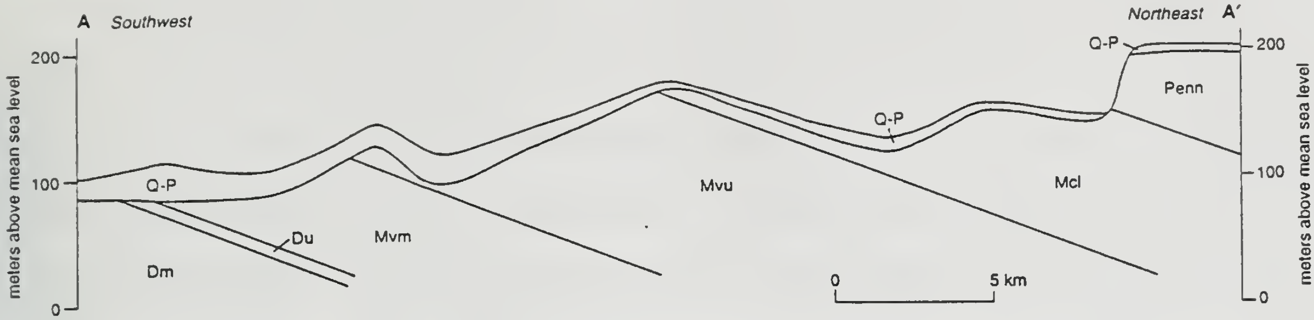
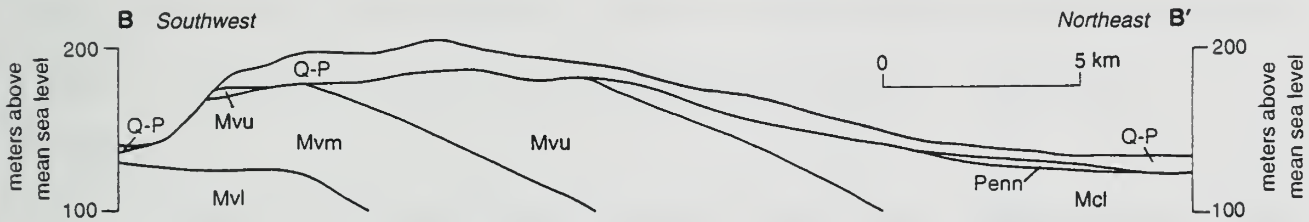


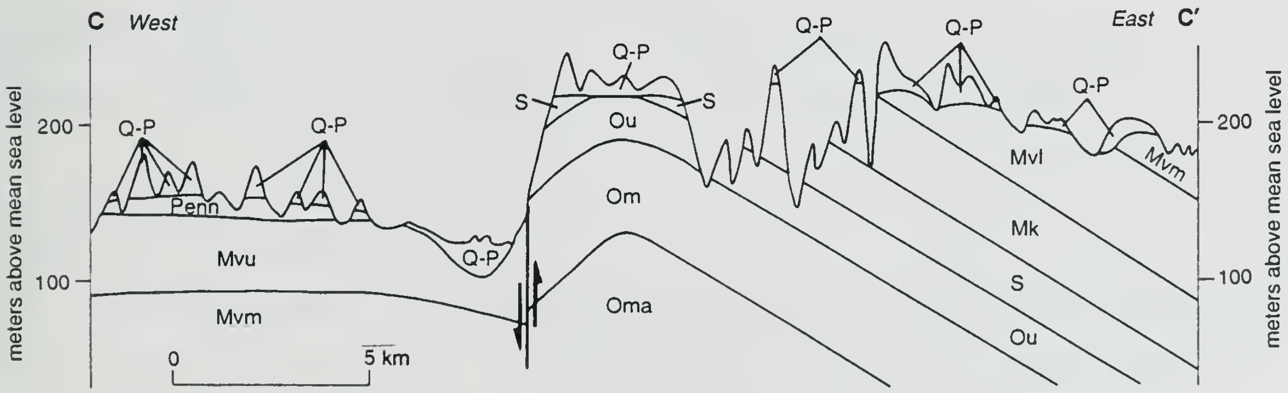
Figure 7. Karst map for the east part of the Shawnee Hills karst region. Geology modifed from Willman et al. (1967).



A. Cross-section of the Shawnee Hills karst region, modified from Weller and Ekblaw (1940) and Willman et al. (1967).



B. Cross-section of the Salem Hills Plateau karst region, modified from Weller and Weller (1939) and Willman et al. (1967).



C. Cross-section of the south part of the Lincoln Hills karst region, modified from Baxter (1965, 1970), Reinertsen and Treworgy (1991), Rubey (1952), Schultz (1993), Treworgy (1979), Whiting and Stevenson (1965) and Wilson and Odom (1959).

Figure 8. Cross-sections A-A′, B-B′, and C-C′.

Paint Creek Formation, Vienna Limestone, and the Clore Formation. In most places the Vienna Limestone is too thin for the significant surface expression of karstic features. Within the Clore Formation, sinkholes generally are found in the Ford Station Limestone Member, which contains the thickest limestone in the formation. Sinkholes in the Kinkaid Limestone are most commonly within the Goreville Limestone Member, but can occur within the Negli Creek Limestone Member and, in the west part of the Shawnee Hills, within the Cave Hill Shale Member where its carbonate content is higher. The Goreville is absent in the east part of the Shawnee Hills area. A few sinkholes are associated with the Hardinsburg Sandstone which probably formed as a result of dissolution of the underlying Haney Limestone Member. In the west portion of the Shawnee Hills, some sinkholes occur where thin Pennsylvanian Caseyville Sandstone forms the bedrock surface. We suggest that these sinkholes formed as a result of dissolution of the underlying Goreville Limestone Member of the Kinkaid Limestone.

Groundwater in the counties of the Shawnee Hills karst region is available from sources that include Silurian and Devonian carbonate rocks, Mississippian Valmeyeran limestones, and Mississippian Chesterian limestones and sandstones. Solution-enlarged crevices of Valmeyeran limestones, and faulting and crevice development in the Chesterian rocks enhanced the permeability of these rocks. The carbonate rocks of the Shawnee Hills karst region are used for rural, municipal and industrial water supplies (Pryor, 1956).

Salem Plateau Karst Region

The region adjacent to the Mississippi River just south of East St. Louis is often referred to as the "sinkhole plain" because it contains a high density of sinkholes (Figures 5, 9, 10). It is also part of the Salem Plateau Section of the physiographic provinces of Leighton et al.

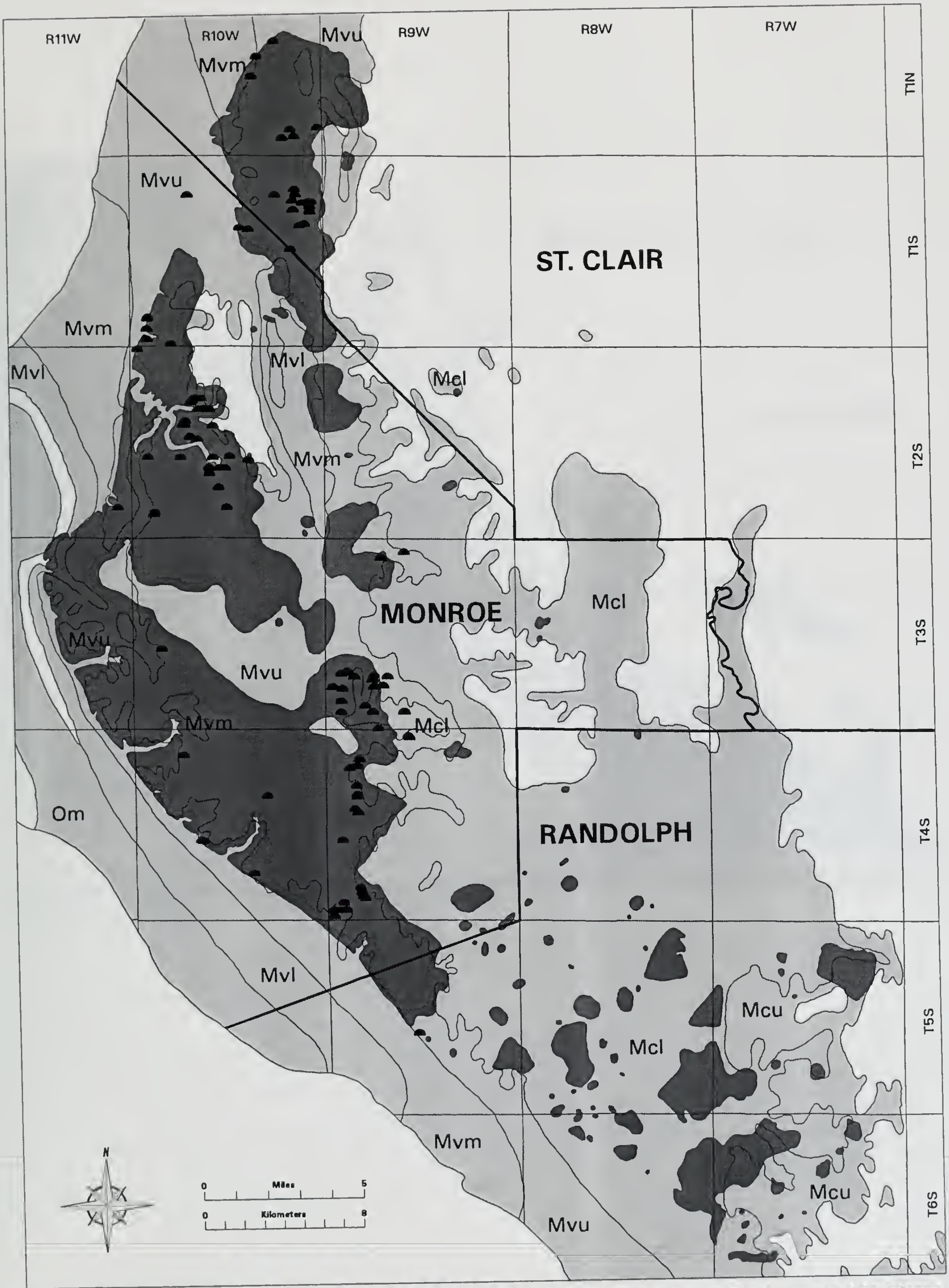


Figure 9. Karst map for the north part of the Salem Plateau karst region. Geology modifed from Willman et al. (1967).

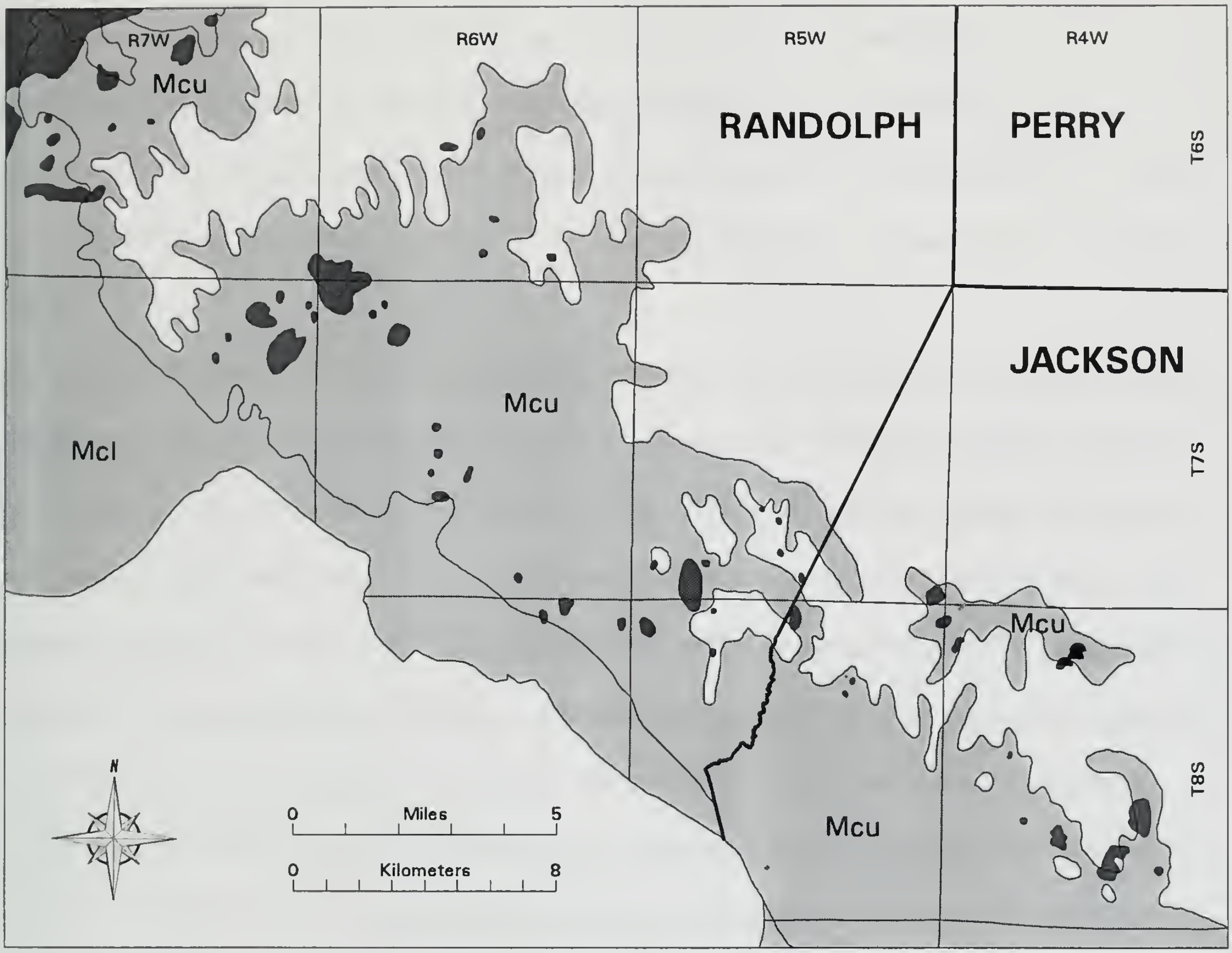


Figure 10. Karst map for the south part of the Salem Plateau karst region. Geology modifed from Willman et al. (1967).

(1948). Approximately 10,000 sinkholes, numerous karst springs, and the largest caves in Illinois are found in this region (Panno, 1996). The bedrock geology of St. Clair, Monroe, and Randolph Counties consists of Mississippian and Pennsylvanian limestone, dolomite, sandstone, shale, claystone and coal (Figure 8B). The structural geology of the area (anticlines), relatively thin glacial drift, and close proximity to the Mississippi River are responsible for the exposure of these rocks in these counties. Drift thickness in this area is typically less than 15 m, but may exceed 15 m in and adjacent to stream valleys (Horberg, 1950).

Caves and sinkholes occur in Mississippian strata ranging from the Valmeyeran Salem Limestone to the Chesterian Kinkaid Limestone. Many of the sinkholes (Weller, 1939) and probably many of the caves occur in the St. Louis Limestone. Solution features in the St. Louis are primarily responsible for the widespread karst topography in the west part of the region. The trends of long caves in this region are parallel or subparallel to the axial trend of major structures in the area. Anticlines, synclines and major cave systems trend northwest-southeast in St. Clair and Monroe Counties. Many caves in this area formed as surface waters entered bedding planes at outcrops and through fissures in near-surface bedrock. Dominant routes for the waters migrating along bedding planes eventually formed small conduits (typically about 10 cm in diameter) that down cut over time to form large solution cavities. The remnants of these initial conduits are visible in parts of Illinois Caverns and Foglepole Cave in Monroe County. These caves are relatively large in diameter (5 m or greater), and extensive (several have more than 5 km of traversable passages). They are typical of the "branchwork" type (per classification scheme of Palmer, 1991), and form as solution tributaries along bedding planes in the limestone bedrock; thus, their passages are characteristically sinuous in plan view.

Sinkholes also are abundant in areas underlain by the Salem and Ste. Genevieve Limestones and are often connected to underlying cave systems. Sinkholes are rarely associated with the Downeys Bluff Limestone Member of the Paint Creek Formation, Beech Creek Limestone Members (and perhaps in the overlying Fraileys Shale Member) of the Golconda Formation, and Vienna Limestone. The few sinkholes associated with the Cypress Sandstone probably formed by dissolution and collapse of the underlying Ridenhower Member of the Paint Creek Formation.

Groundwater resources in these counties occur in the Valmeyeran strata that include the St. Louis Limestone and the overlying Aux Vases Sandstone. Springs and wells in the St. Louis are sources of groundwater for domestic and rural supplies in the west part of the karst region. The Aux Vases Sandstone underlies part of this region, and in the east, forms the bedrock surface below thin glacial drift. This sandstone is also a reliable source of groundwater in this region. The thin glacial drift, however, does not offer much protection for shallow groundwater supplies in this area. Wells drilled through the overlying Chesterian karst aquifer and into the underlying Aux Vases Sandstone typically are not cased through the karstic zone and localized contamination may occur by this route (Panno et al., 1996).

Lincoln Hills Karst Region

Karstic features in the Lincoln Hills karst region (Figures 5, 11, 12) occur in Adams, Pike, Calhoun, Greene, Jersey, and Madison Counties in Middle Ordovician Kimmswick Limestone, Silurian (Alexandrian Series) Sexton Creek Limestone, and Mississippian (Valmeyeran Series) Burlington, Salem, St. Louis, and Ste. Genevieve Limestones (Lamar, 1928; Rubey, 1952) (Figure 8C, 13A). Rubey (1952) and Baxter (1965) described the lithologies of the carbonate strata of the region. The Kimmswick Limestone dominantly

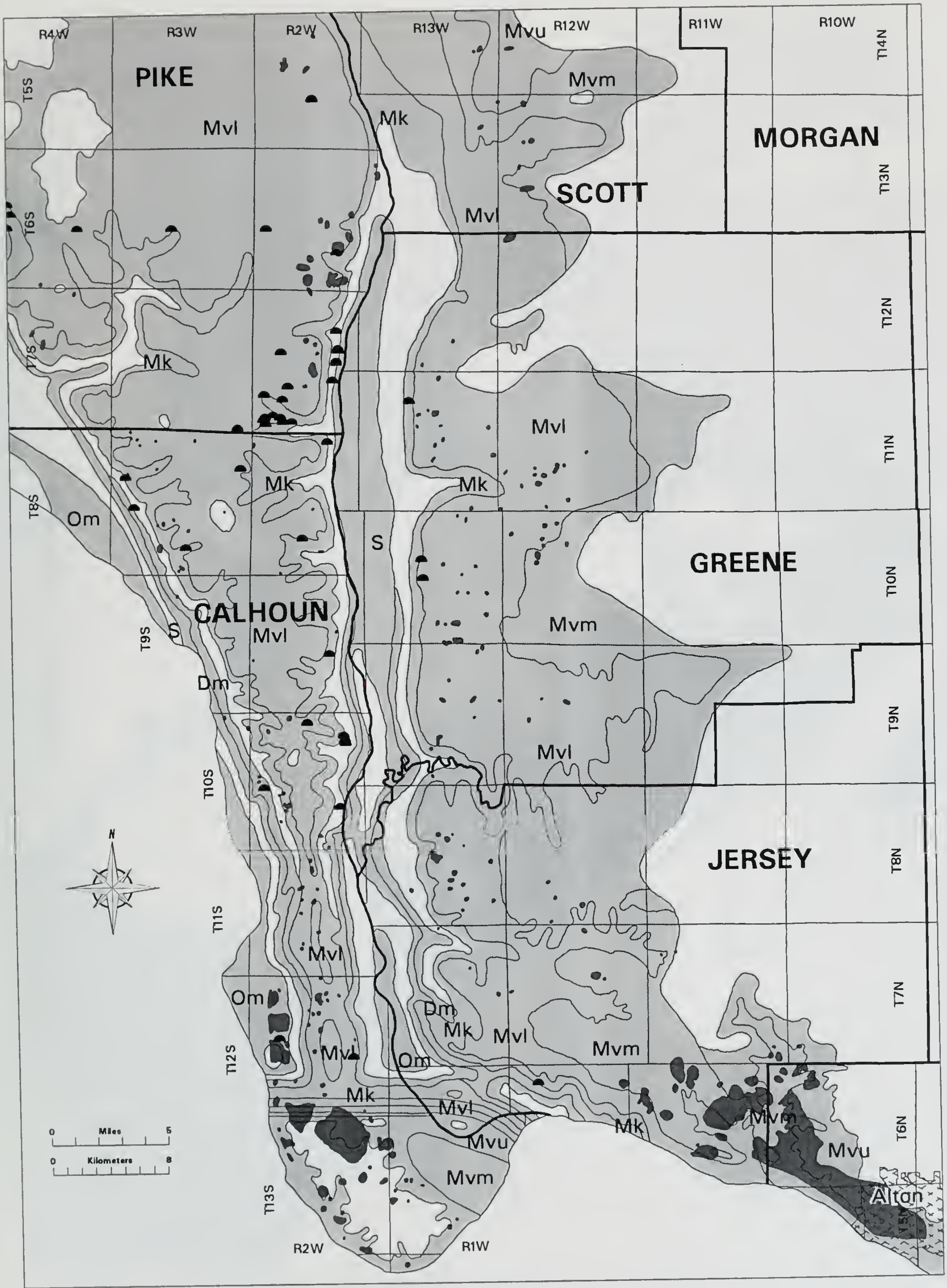


Figure 11. Karst map for the south part of the Lincoln Hills karst region. Geology modifed from Willman et al. (1967).

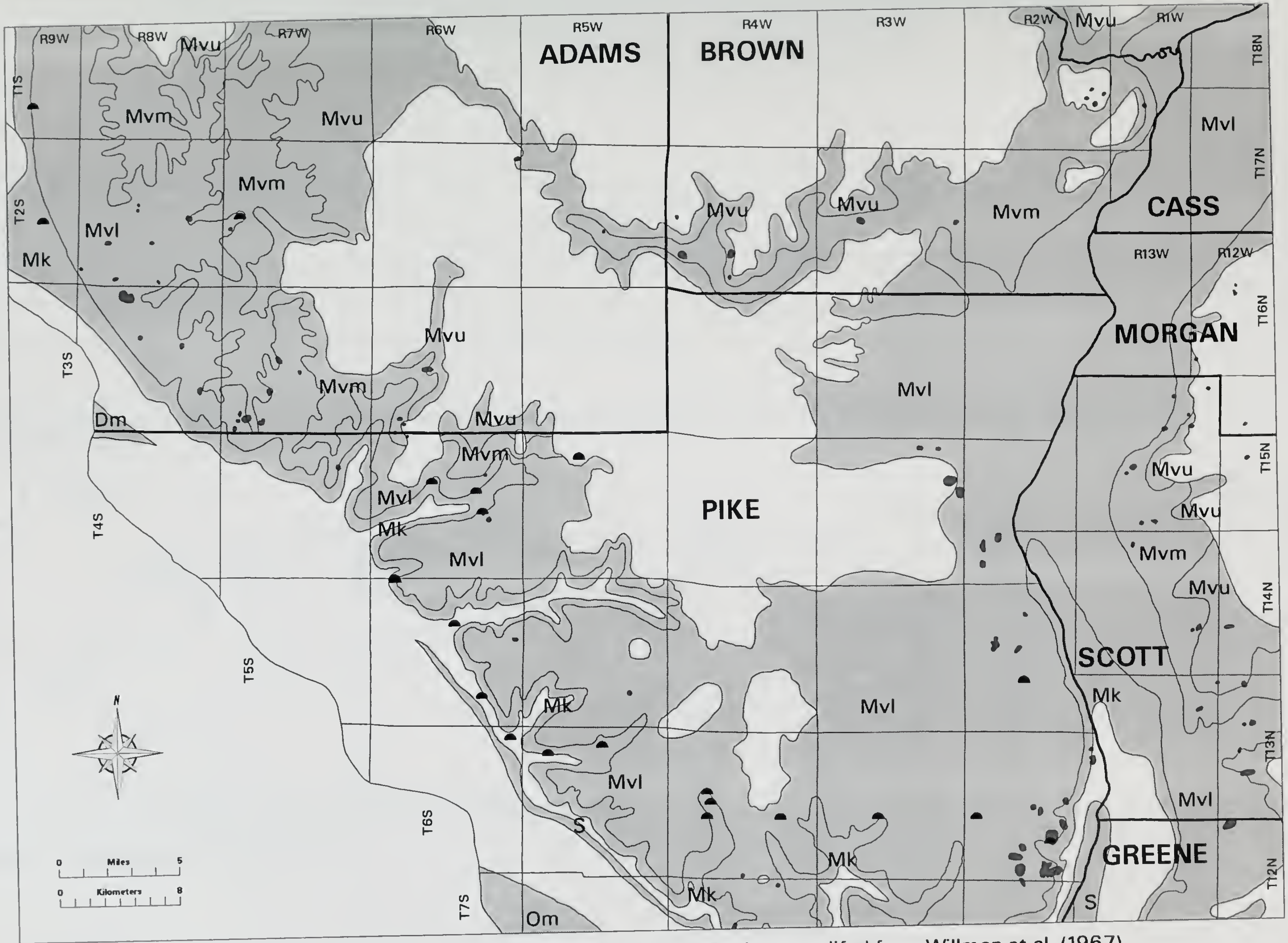
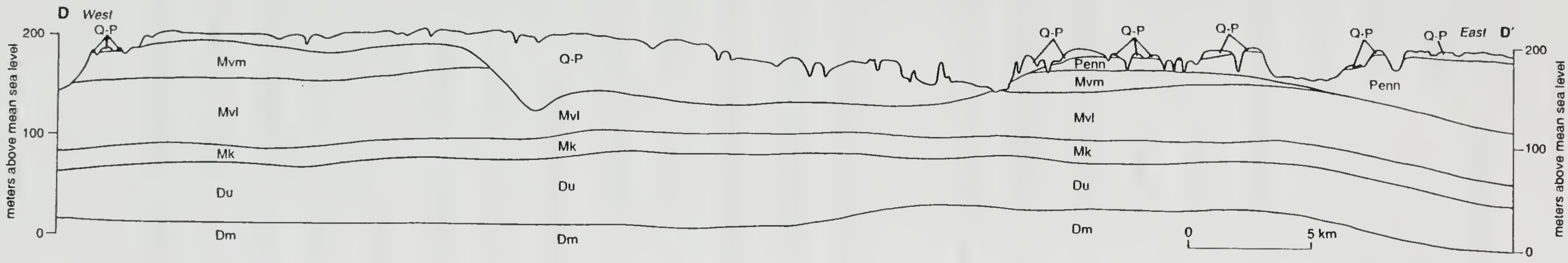
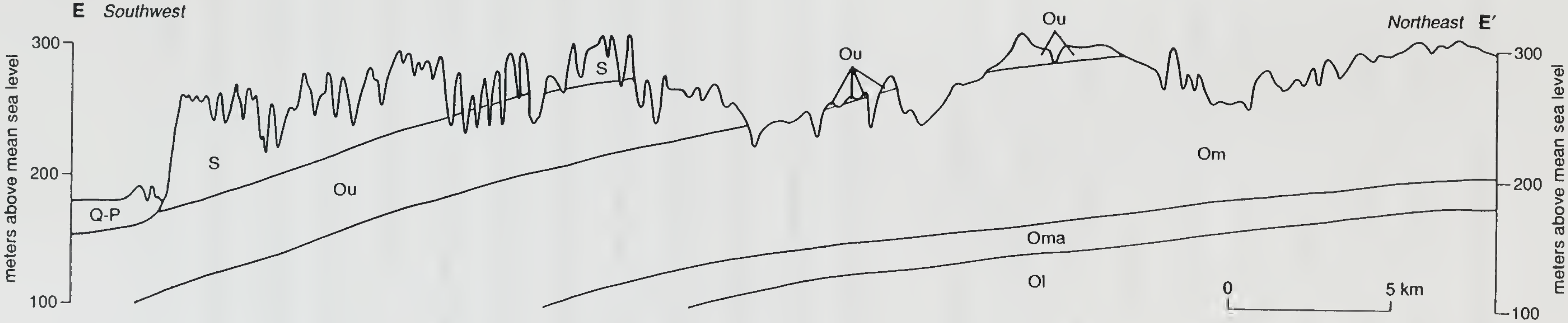


Figure 12. Karst map for the north part of the Lincoln Hills karst region. Geology modifed from Willman et al. (1967).



A. Cross-section of the north part of the Lincoln Hills karst region, modified from Harvey (1964), Hinds (1917), Krey (1924), Morse and Kay (1915), Wanless (1957), and Whiting and Stevenson (1965).



B. Cross-section of the Driftless Area karst region, modified from Willman et al. (1967).

Figure 13. Cross-sections D-D′ and E-E′.

consists of fine- to coarse-grained, massive limestone. The Sexton Creek Limestone ranges from a fine-grained limestone in the north part of the area to a porous dolomite in the south part. The Burlington is a cherty, coarse-grained, crinoidal limestone. The overlying Keokuk Limestone is lithologically similar and is difficult to distinguish in many places. The Keokuk probably contains karstic features, although this investigation has not verified such occurrences. The Salem consists of a coarse-grained limestone that locally contains dolomite. The overlying St. Louis Limestone is dominated by fine- to very fine-grained, cherty limestone, but also contains variable amounts of dolomite, conglomeratic limestone, and arenaceous and oolitic limestone. The Ste. Genevieve Limestone consists of very fine- to medium-grained limestone that locally varies from being argillaceous, to arenaceous, and to oolitic.

Most of the sinkholes in the west part of the Lincoln Hills karst region occur in either the Kimmswick or St. Louis Limestones (Rubey, 1952). The sinkholes in the east part of the region, in and near Alton, are associated primarily with the St. Louis and Ste. Genevieve Limestones (Figures 3, 11). Many of the sinkholes occur in relatively thick loess deposits that overly the limestones and appear to have formed by stoping of the loess into voids in the limestone. Some of these sinkholes, particularly in southernmost Calhoun County, contain a thin layer of Pennsylvanian strata between the underlying limestone and the overlying loess (Rubey, 1952). Sinkholes in this region are typically shallow, bowl-shaped depressions, many of which contain trees or are filled with water and surrounded by trees.

Sand and gravel, dolomite, limestone, and sandstone aquifers are used in the Lincoln Hills karst region for domestic water supplies. Wells and springs in the Mississippian Burlington and Keokuk Limestones are the main sources of domestic water from bedrock. Wells also have been drilled into Devonian and Silurian rocks, but these are not as productive.

The Salem-St. Louis limestone interval in Jersey County is sufficiently thick and creviced to serve as a supply for rural wells (Bergstrom and Zeizel, 1957).

Driftless Area Karst Region

Near-surface and exposed carbonate bedrock in the Driftless Area of northwest Illinois (Jo Daviess and northwest Carroll Counties) are of Middle Ordovician or Silurian age (Figures 13B, 14). The Middle Ordovician Platteville Group is composed of very fine-grained limestone mottled with dolomite. The Galena Group overlies the Platteville Group and consists of limestone and dolomite, except for a basal shaley limestone and dolomite interval (Willman et al., 1975). Karstic features also occur in Silurian (Alexandrian and Niagaran Series) bedrock. The Silurian is divided into the Mosalem, Tete des Morts, Blanding, and Hopkinton Formations (Willman, 1973; Bunker et al., 1985). These rocks are medium- to coarse-grained, locally cherty dolomite (Heyl et al., 1959). Most, if not all, of the sinkholes in this area occur in the Niagaran Hopkinton Formation (Brian Witzke, Iowa Geological Survey, personal communication).

Both caves and sinkholes are indicators of karst terrain in the Driftless Area; however, caves are the dominant feature in this region (Figures 5, 14) in Illinois. Most of the caves occur in the Galena Group (Trowbridge and Shaw, 1916; Heyl et al., 1959; Brown and Whitlow, 1960). Bretz and Harris (1961) described a cave in Carroll County in Silurian dolomite, probably in strata younger than the Hopkinton Formation. The caves are predominantly solutionally-widened joints, according to descriptions by Bretz and Harris (1961), and Webb et al. (1994). Caves of this type are referred to as "network" caves (Palmer, 1991), are fracture-controlled, and often follow solution features along near-vertical fracture planes.

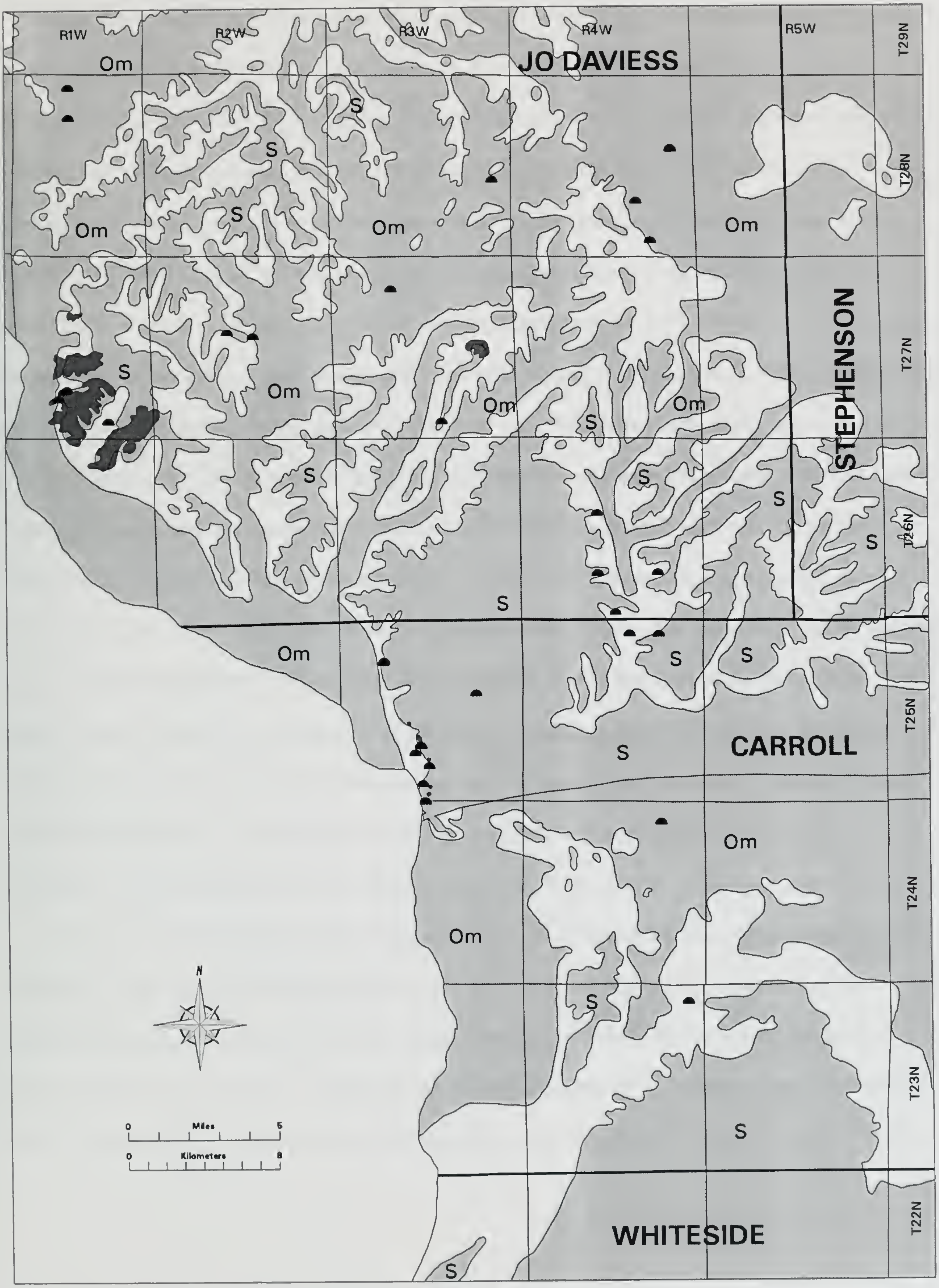


Figure 14. Karst map for the Driftless Area karst region of northwest Illinois. Geology modifed from Willman et al. (1967) and Kolata and Buschbach (1976).

Few sinkholes in this area are evident on topographic maps and aerial photos. However, both Trowbridge and Shaw (1916) and Heyl et al. (1959) reported sinkholes to be locally common in Silurian rocks. We observed several sinkholes of this diameter and of smaller sizes in regolith underlain by Hopkinton dolomite. Heyl et al. (1959) noted that sinkholes are larger (averaging about 30 m in diameter) and more abundant in the Silurian dolomite than in the Ordovician Galena Group. We did not study any sinkholes in the Ordovician strata in this area. The number of sinkholes associated with Ordovician rocks drastically increases towards the northwest into Iowa where these strata are less dolomitic (Heyl et al., 1959; Hallberg and Hoyer, 1982). The relationship between soils type and thickness (from stack unit maps by Berg and Kempton, 1988), and the locations of sinkholes shown on our maps indicates that sinkholes mostly occur in areas dominated by loess, silt and diamicton of the Quaternary Glasford Formation. They are most common in areas where these materials are less than 6 m thick, and within one to two kilometers of a stream valley. In the Driftless Area, sinkholes are most common adjacent to the Mississippi River valley. Sinkholes commonly occur near stream valleys because of the gradual lowering of the piezometric surface (i.e., the water table) near low-lying areas by surface erosion and the associated collapse of formerly water-saturated sediments (cover-collapse sinkholes) into solution-enlarged fissures. This mechanism was proposed by Ford (1964) for sinkhole formation in the Mendip Hills of Britain.

The limestones and dolomites of the Platteville and Galena Groups, where they are not overlain by shale of the Maquoketa Group, are an important source of groundwater in northwest Illinois, and in most of the northern third of the state. Groundwater occurs in joints, fractures, and solution cavities. Groundwater also occurs in Silurian dolomite on ridges where it is perched on underlying Maquoketa shale. This dolomite similarly contains crevices

and solution features that provide groundwater for farm and domestic supplies (Hackett and Bergstrom, 1956).

North-Central Karst Region

An area that straddles the Rock River in Ogle and Lee Counties in north-central Illinois comprises the North-Central karst region (Figures 5, 15). Carbonate bedrock units in north-central Illinois consist of the Lower Ordovician Shakopee Dolomite of the Prairie du Chien Group and the Middle Ordovician Platteville and Galena Groups (Figure 16A). Because of the north-south trending Wisconsin Arch, these rocks are exposed along the tributaries of the Rock River from near Rockford (Winnebago County) to near Dixon (Ogle County) (Willman et al., 1967). The rocks are also exposed in road cuts and quarries on the south side of Rockford, and in road cuts north of Freeport (Stephenson County). Knappen (1926) first described the lithology of these strata near Dixon. The Shakopee Dolomite is a fine-grained, porous, argillaceous dolomite which locally contains shale and sandstone. The Galena Group consists of a porous, cherty, very fine-grained to very coarse-grained dolomite. The Platteville Group consists of a very fine- to coarse-grained, interbedded dolomite and limestone that locally contains argillaceous intervals. The Galena-Platteville interval has an average thickness of approximately 115 m (Foster, 1956).

Sinkholes are the principle evidence for karstic development in the Byron-Dixon area and occur mostly in near-surface or exposed carbonate bedrock (Bretz, 1923; Knappen, 1926). A few sinkholes also occur in soils overlying the St. Peter Sandstone, but we suggest that these are due to dissolution of the underlying Shakopee Dolomite and collapse of both the overlying sandstone and soil. Knappen reported that over 75% of the sinkholes occur where limestone of the Platteville Group is overlain by loess and silt, and diamicton of the

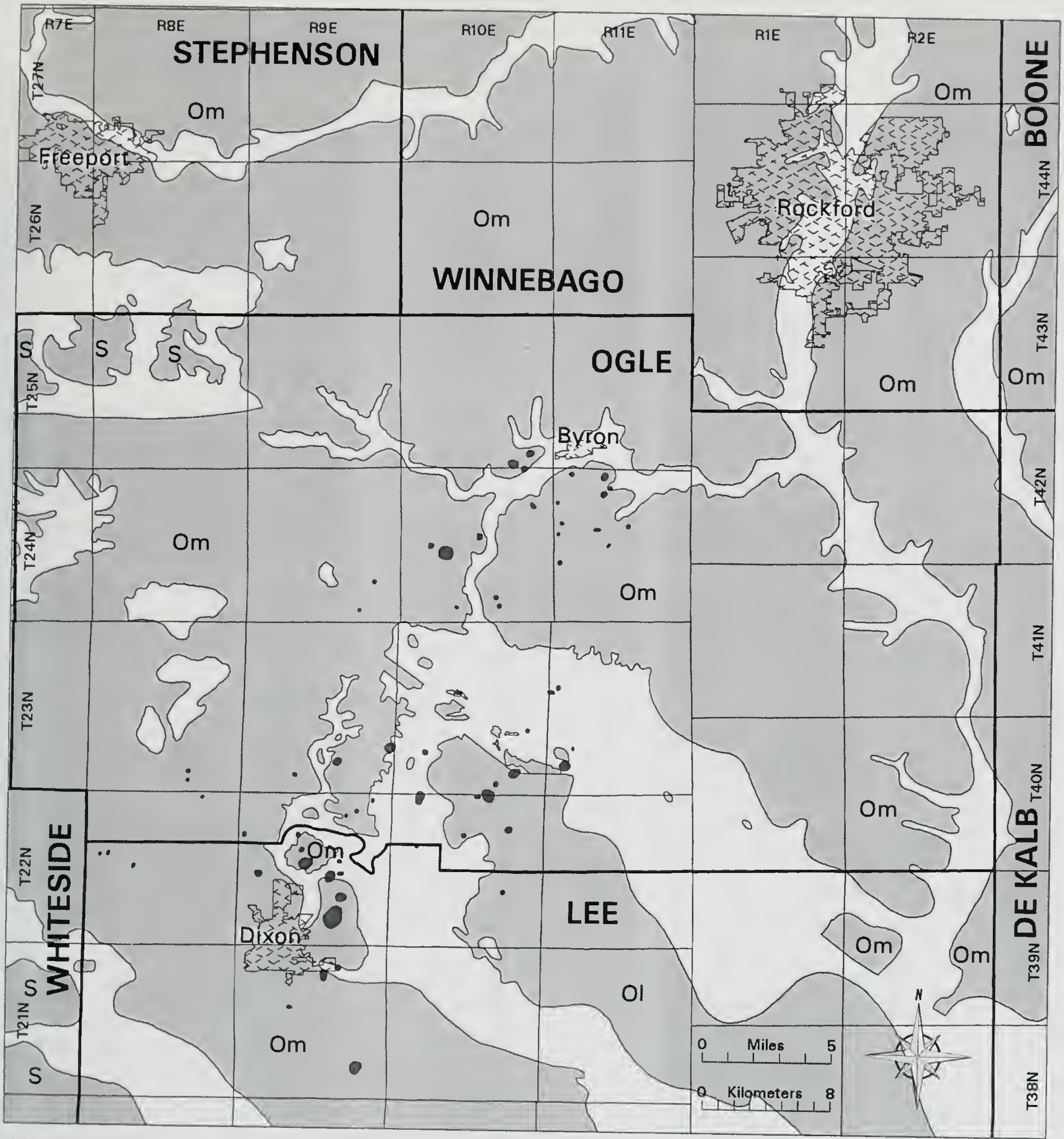
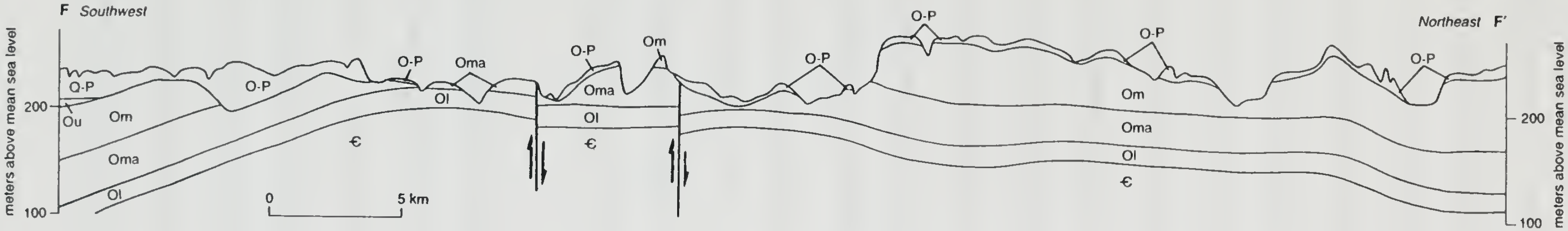
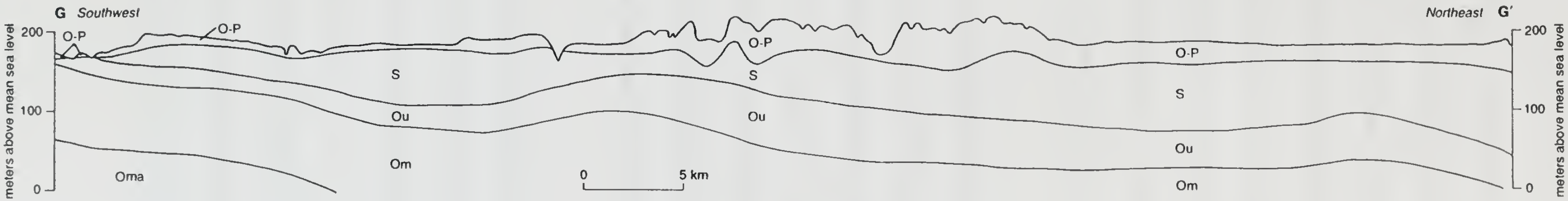


Figure 15. Karst map for the North-Central karst region. Geology modifed from Willman et al. (1967) and Kolata et al. (1978).



A. Cross-section of the North-Central karst region, modified from Bretz (1923), Kolata et al. (1978), Knappen (1926), Reinertsen (1990), and Templeton and Willman (1952).



B. Cross-section of northeastern Illinois, modified from Bretz (1939, 1955), Buschbach and Heim (1972), Culver (1923), Fisher (1925), and Savage (1925).

Figure 16. Cross-sections F-F′ and G-G′.

Quaternary Glasford Formation. Comparison of the karst maps of this paper with stack-unit maps developed by Berg and Kempton (1988) indicates that sinkholes commonly occur in areas where the bedrock is dominated by this stratigraphic sequence, where the overlying Quaternary cover is less than 6 m thick, and are located within several kilometers of stream valleys associated with the Rock River. The proximity of sinkholes to the stream valleys may be the result of reactivation of paleokarstic features. The gradual lowering of the piezometric surface (i.e., the water table) as stream valleys erode downward and the associated collapse of formerly water-saturated sediments (cover-collapse sinkholes) into solution-enlarged fissures may also be a factor in this area.

There are no verified cave entrances in the North-Central karst region; however, quarrying operations reportedly destroyed a cave in limestone of the Platteville Group northeast of Dixon (Knappen, 1926). We observed a sediment-filled cave opening in the Gregory-Anderson Co. quarry on the south edge of Rockford. At the northeastern edge of the region, Bretz (1923) referred to an unverified cave reportedly located south of Rockford near the Winnebago-Ogle county border. Bretz also reported several occurrences of open cavities (probably solution features) in the limestone that were encountered during the drilling of water wells.

Solution-enlarged fissures are common in the road cuts and quarries near Rockford and Freeport. They range in width from 0.25 m in road cuts along Interstate 39 to 8 m wide in the Gregory-Anderson Co. quarry. Despite the common occurrence of fissures in this region, we only mapped sinkholes in the Byron-Dixon area (Figure 15).

Groundwater in north-central Illinois is available in the Galena-Platteville dolomite where joints, fractures, and solution cavities are present and interconnected over a relatively large areal extent. Mills et al. (1993) reported that groundwater flow in the Galena-Platteville

aquifer was primarily through "...subvertical fractures and subhorizontal zones of solution," the latter of which are probably stratigraphic breaks. They noted that hydraulically connected subhorizontal solution features have been identified that extend laterally for at least 1.2 km. The availability of water from these strata is adequate for domestic, farm, municipal, and industrial use (Foster, 1956); however, water-producing zones are distributed irregularly (vertically and horizontally) due to the irregular nature and distribution of the cavities (Csallany and Walton, 1963).

Other areas containing karstic features

Karstic features have been documented in carbonate bedrock in areas outside of the five karst regions. These areas are mostly covered with unlithified Quaternary deposits. In addition, some of the features occur in carbonate bedrock in areas where the bedrock is overall predominantly noncarbonate.

Northeast Illinois

The bedrock of northeast Illinois contains a few, widely dispersed karstic features. This area is most covered with regolith and outcrops are few in number and size. The paucity of karstic features in a relatively large area (from Lake to Kankakee Counties) and definite evidence of widespread extant karstification processes are the reason for not referring to this area as a karst region.

Silurian (Alexandrian and Niagaran Series) rocks comprise most of the bedrock surface in this area. These rocks are on the northeast flank of the Kankakee Arch, the axis of which plunges to the southeast and separates the Illinois Basin from the Michigan Basin (Visocky et al., 1985). These rocks are typically buried under 30 m or more of clayey diamicton and lake

sediments (Figure 16B). In this area, the Alexandrian Series (lowermost Silurian) is divided into the Wilhelmi, Elwood, and Kankakee Formations which are chiefly composed of dolomite (Willman, 1973). The Wilhelmi Formation is an argillaceous dolomite with coarse silt, fine sand and shale partings near its base. The Elwood Formation is an abundantly cherty, pure to slightly argillaceous dolomite. The Kankakee Formation is a relatively pure dolomite that also contains shale partings. The younger Niagaran Series (middle Silurian) is divided into the Joliet, Sugar Run and Racine Formations. The lithology of these formations ranges from pure dolomite to silty, argillaceous and cherty dolomite containing some thin shale beds. Reefs occur locally in the Racine Formation (Willman, 1973). The upper surface of the Niagaran Series dolomite is an erosional surface (Willman, et al., 1975) and is creviced in outcrop.

Otto (1963) and Buschbach and Heim (1972) interpreted the buried Silurian dolomite of northeast Illinois as a karstic surface on the basis of seismic refraction, borehole, and outcrop data. The latter study covered over 2000 square kilometers of the greater Chicago area, most of Cook County, east Du Page County, and part of northern Will County. Buschbach and Heim described the bedrock as "...a dissected surface with numerous hills, northeast-southwest to east-west trending valleys that slope to the east, and enclosed depressions." Rare and typically small caves occur in Kane and Kankakee Counties where Silurian dolomite is exposed along stream valleys. Zeizel et al. (1962) stated that "enlargement of joints, fractures, and bedding planes by solution has taken place" typically at or near the bedrock surface. Otto (1963) prepared a detailed map of the bedrock surface near Joliet where abundant karstic features had been exposed in a deep excavation for a power plant site. Conversely, in the younger Niagaran dolomite, Bloom (1978) described only minor karstic features found along and interpreted to be controlled by joints and bedding planes.

During our field work, we found solutionally widened fractures and caves exposed in

quarries, excavations, and a few natural bedrock exposures. These caves and fractures are typically filled with very fine-grained material that renders these features ineffective as conduits. However, exhumation and flushing of fill materials could result in the rejuvenation of a conduit system. Solutionally-widened fractures, sinkholes, solution features (i.e., horizontal grooves), and caves were observed in Lehigh Quarry, Kankakee River State Park (Kankakee County). Active sinkholes and sinking ephemeral streams occur near the Illinois River in Will County. Sediment in some karstic features in the Racine Formation in the Lehigh Quarry describe by (Bretz, 1940) contained early to middle Pennsylvanian spores. Much of the buried bedrock surface in northeast Illinois may be classified as paleokarst (per classification scheme of White, 1988). Karstic features such as those along Rock Creek in Kankakee County in the Kankakee Formation may have been exposed by erosion and be classified as exhumed karst. The active sinkholes in Will County may be classified as sinkhole karst.

The Silurian dolomite aquifer in northeast Illinois is the most productive aquifer of the Upper Bedrock Aquigroup (which also includes the Ordovician Galena-Platteville interval and the Ancell aquifer). Specific yields for this aquifer are dependent on the distribution and intensity of crevicing, and the size of the fracture openings. Consequently, specific yields from this aquifer are extremely variable (Visocky et al., 1985). The most productive part of the Silurian dolomite aquifer is the upper 15 m where solution-enlarged fractures are prevalent (Zeizel et al., 1962).

Douglas County

A cave entrance in an abandoned barrow pit and dissolution features in an active quarry are indicators of karst near the village of Tuscola in Douglas County. During

excavation of a barrow pit for material to be used in the construction of the adjacent interstate highway, a small cave was encountered. This pit is just east of Tuscola and the cave was in the floor, which consisted of Devonian limestone. The cave was relatively small but was not filled with sediment, suggesting that karstification processes are active. In a nearby quarry, about 1.5 km east, solutionally widened joints occur in Devonian limestone but appear to be filled with sediment. These karstic features occur in an isolated outcrop/subcrop of limestone, surrounded by predominantly noncarbonate bedrock, at the axis of the LaSalle Anticlinorium. Further study is required to determine additional details on these karstic features and if a karst aquifer is present.

La Salle County

Several sinkholes and a cave are indicators of karst in a small area near the villages of La Salle and Oglesby in La Salle County. A few sinkholes occur in the Late Pennsylvanian LaSalle Limestone southeast of Oglesby. The LaSalle Limestone is the thickest limestone in the otherwise noncarbonate dominated Pennsylvanian strata of Illinois. This limestone is rarely used as a source for groundwater and only for domestic use (R. Brower, ISGS, personal communication).

The cave occurs in the Lower Ordovician Shakopee Dolomite and is about 1.5 km east of La Salle. In this area, the Shakopee is a more widespread bedrock than the LaSalle Limestone, but it is only locally utilized as a groundwater source. Most deep wells obtain water from sandstone strata above and below this dolomite. Where either the LaSalle or the Shakopee are used as aquifers, joints/fractures provide the porosity and they may be solutionally enlarged.

PSEUDO-KARSTIC FEATURES

Karst-like or pseudo-karstic features similar to sinkholes occur in areas where the collapse of abandoned underground mine tunnels have resulted in pit subsidence and associated piping of soil. Soil piping may also take place where drainage in poorly consolidated materials such as loess and sand intersects underground cavities and progressively erodes materials along its flow path. Mine collapse and soil piping often form pit subsidence that may be indistinguishable from sinkholes in true karstic areas.

Underground mines (Figure 17), that act as drains for infiltrating surface water and groundwater, have been responsible for the formation of sinkholes and other subsidence phenomena in Illinois. As shallow (less than 60 m) room and pillar mines collapse, concomitant collapse of overlying poorly consolidated materials, and/or soil piping into these cavities may form sinkholes in overlying terrains (e.g., Bauer et al., 1993). The mines also may be responsible for groundwater and surface water contamination due to their efficiency in transporting surface-derived contaminants to groundwater and surface waters. Underground mines are located in Ordovician rocks in Jo Daviess County, zinc and lead ores were extracted, in Mississippian rocks in Pope and Hardin Counties, where fluorspar was extracted, and in the predominantly noncarbonate Pennsylvanian rocks, where coal was extracted. Coal mining is responsible for most of the mined out areas in Illinois. The locations of these areas are discussed in Treworgy et al. (1989) and Damberger et al. (1984).

Soil piping occurs as a result of surface water draining rapidly through the soil into an open space (e.g., mine openings, fissures associated with mine-collapse). As the pressure of the infiltrating water increases in the soil, the soil fails and collapses into the openings. Eventually, cavities are formed at depth along the flow path as the soils collapse or stope

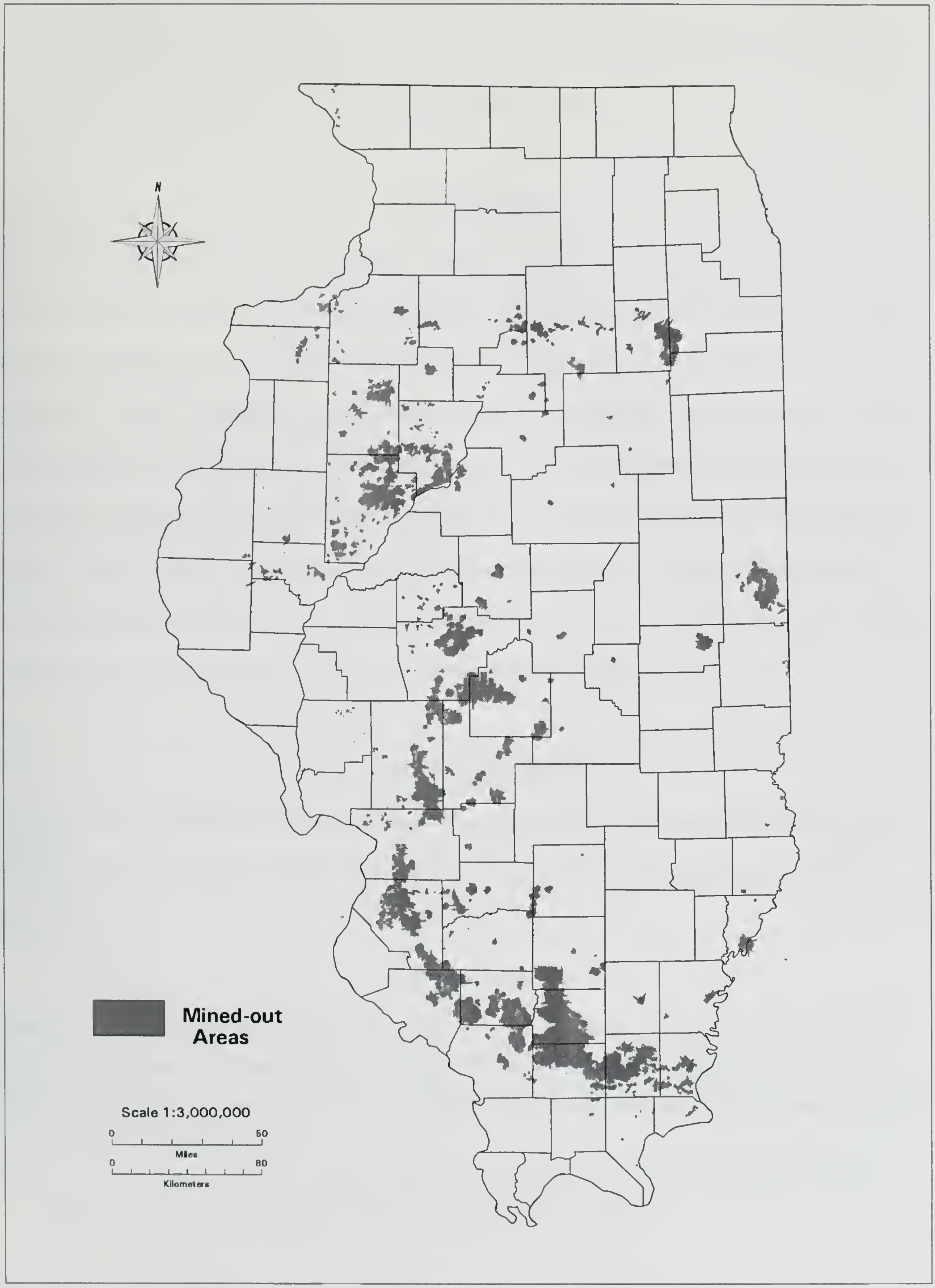


Figure 17. Map showing mined-out areas where psudo-karst features are likely to occur.

upward into the overlying materials. Continuous upward stoping of soil eventually results in the formation of a sinkhole at the surface (e.g., White, 1988).

CONCLUSIONS

Approximately 25% of the bedrock surface of Illinois is carbonate rock, and approximately 9% includes the five karst regions. In these regions, which are on the margins of the Illinois Basin and along structures within the basin, carbonate bedrock is either exposed or subcrops beneath glacial diamicton, loess, and other sediments. Karstic features are concentrated in the Driftless Area in northwest Illinois, north-central Illinois, the Lincoln Hills of the west part of the state, the Salem Plateau of southwest Illinois, and the Shawnee Hills of southern Illinois. A few caves and sinkholes are found in northeast Illinois, and La Salle and Douglas Counties, and are associated either with carbonate rocks along the LaSalle Anticlinorium or the northeast flank of the Illinois Basin (Kankakee Arch).

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