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# **GEOLOGY OF THE LICK CREEK QUADRANGLE JOHNSON, UNION, AND WILLIAMSON COUNTIES, SOUTHERN ILLINOIS**

**W. John Nelson and C. Pius Weibel**

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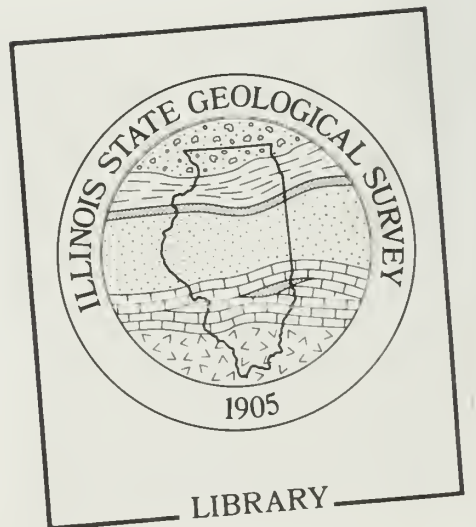
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ILLINOIS STATE GEOLOGICAL SURVEY  
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**Cover Photo** Graben created by landslide on north side of Grassy Creek



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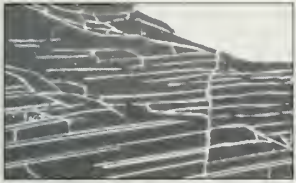
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## ABSTRACT

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The Lick Creek Quadrangle comprises parts of Johnson, Union, and Williamson Counties and lies along the southwest margin of the Illinois Basin.

Outcropping bedrock strata are of Chesterian (late Mississippian) and Pennsylvanian age. Exposed Mississippian strata are about 450 feet thick and consist of alternating limestone, shale, and sandstone. These rocks are assigned to the Pope Group and divided into five formations: Menard Limestone (oldest), Palestine Formation, Clore Formation, Degonia Formation, and Kinkaid Limestone. Pope Group sediments were deposited in shallow subtidal to supratidal environments on a tectonically stable shelf. Siliciclastic intervals reflect episodes of deltaic progradation.

The Caseyville Formation (Morrowan; Lower Pennsylvanian) unconformably overlies the Kinkaid Limestone. The Caseyville is composed of thick, bluff-forming sandstone that is interbedded with slope-forming intervals of shale, siltstone, and thin, lenticular coal. Caseyville sandstones are quartz arenites and commonly contain quartz pebbles. Individual sandstone units become

thicker and coarser grained eastward, and the Caseyville thickens eastward from about 180 to 400 feet. Subsidence evidently was more rapid in the eastern part of the quadrangle than in the western part during Caseyville time.

The Tradewater Formation (late Morrowan to early Desmoinesian; Lower and Middle Pennsylvanian) conformably overlies the Caseyville. The Tradewater consists of lithic arenite interbedded with shale, siltstone, and thin coal. Maximum thickness of the Tradewater is about 300 feet; its top is eroded. The Caseyville and Tradewater Formations represent shallow marine, estuarine, and deltaic sediments; they have not been differentiated in the western part of the quadrangle.

Quaternary deposits in the study area include unlithified clay, silt, and sand and gravel. Diamicton of the Glasford Formation has been mapped in the northern part of the quadrangle. The Glasford is interpreted as ice-margin and terminal moraine sediment at the extreme southern limit of Illinoian continental glaciation. The Glasford filled preglacial valleys; streams have subsequently

cut new channels superimposed into bedrock. Other Quaternary sediments in the study area are interpreted as alluvium, colluvium, talus, and loess.


Paleozoic rocks in the quadrangle dip uniformly northeast at an average of less than 1°. The only tectonic fault is a southwest-dipping thrust fault that has about 10 feet of throw. A few normal faults having throws of several feet were observed in roadcuts; they probably are products of soft-sediment deformation.

Limestone is the only known significant mineral commodity in the study area. Several quarries have operated in the Kinkaid Limestone in and near the Lick Creek Quadrangle. Coal beds are too thin and lenticular to be of economic interest. Nine unsuccessful oil and gas exploration holes have been drilled in the quadrangle. The deepest formation penetrated was the Ste. Genevieve Limestone (Valmeyeran; middle Mississippian).

Landslides are a hazard on steep slopes, especially those underlain by the Glasford Formation. Sinkholes and other karst features occur in some areas underlain by limestone, particularly the Kinkaid Limestone.

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## INTRODUCTION

This report accompanies the Lick Creek geologic quadrangle map (Weibel and Nelson 1993) and is one of a series of Illinois State Geological Survey (ISGS) publications on the geology of southern Illinois. This study was prepared under the auspices of the Cooperative Geologic Mapping Program (COGEOMAP) and jointly supported by the United States Geological Survey (USGS) and the ISGS. COGEOMAP produced maps suitable for (1) understanding local and regional geologic history, (2) exploring mineral resources, (3) assessing geologic hazards, and (4) planning for land use.

### Geography and Physiography

The Lick Creek Quadrangle is in southernmost Illinois between latitudes 37°30' and 37°37'30" N and longitudes 89°00' and 89°07'30" W (fig. 1). Highway access to the area is provided by Interstate highway 57 (I-57) between Marion and Cairo. The Lick Creek and Goreville interchanges are within the quadrangle. Paved and graveled county roads provide access to most of the study area, except for areas around the Crab Orchard National Wildlife Refuge, where access is by foot trails. Two unincorporated villages, Lick Creek and Wayside, are in the quadrangle, but the latter is a "ghost" town. Approximately three-fourths of the quadrangle is privately owned, and most of the remainder is in the Shawnee National Forest.

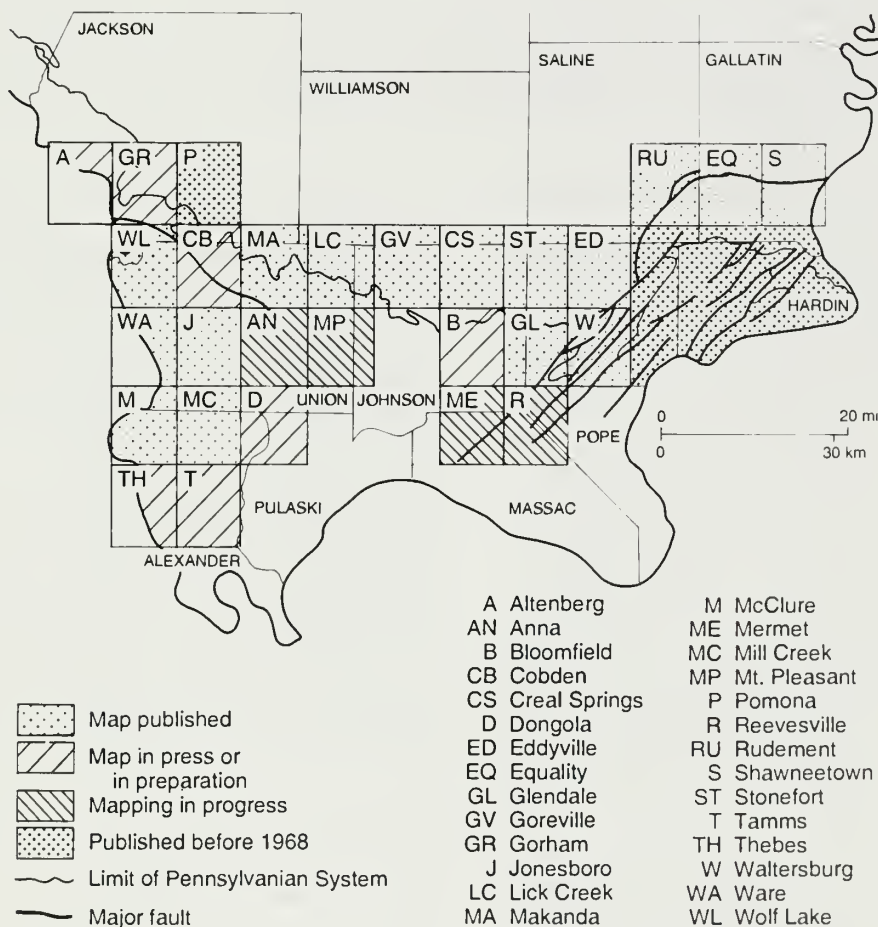
The quadrangle is within the Shawnee Hills Section (Leighton et al. 1948) of the Interior Low Plateaus Province (Fenneman 1938). The area consists of a dissected plateau, whose higher ridges generally are composed of Pennsylvanian sandstone, particularly of the Caseyville Formation. Streams eroding the Pennsylvanian sandstones have formed narrow valleys and canyons with high bluffs, whereas those eroding the less resistant Mississippian limestones, shales, and thin sandstones have formed broad, open valleys. A karst topography

has developed in some areas that are underlain by thicker Mississippian limestones.

The highest elevation in the quadrangle is more than 860 feet above mean sea level, in the ½ SW SW of Section 18, T11S, R2E. Upland Mississippian strata generally are above 450 feet, and Pennsylvanian strata generally are above 550 feet. Bottomland elevations average about 400 feet. The lowest elevation is less than 390 feet in the southeast corner of the quadrangle along Lick Creek. Total relief is 470 feet; local relief is as much as 250 feet.

Lick Creek and its tributary Buck Branch drain most of the southern half of the quadrangle. Bradshaw Creek drains the southeastern corner. Both creeks are part of the Cache River watershed and are separated from north-flowing drainages in the quadrangle by a major east-west divide. The north-flowing streams, including Wolf Creek, Middle Wolf Creek, Little Wolf Creek, Little Grassy Lake, and Devils Kitchen Lake, are part of the Big Muddy River watershed.

Climate is warm and temperate, with an average annual temperature



**Figure 1** Location map shows quadrangles geologically mapped under COGEOMAP.

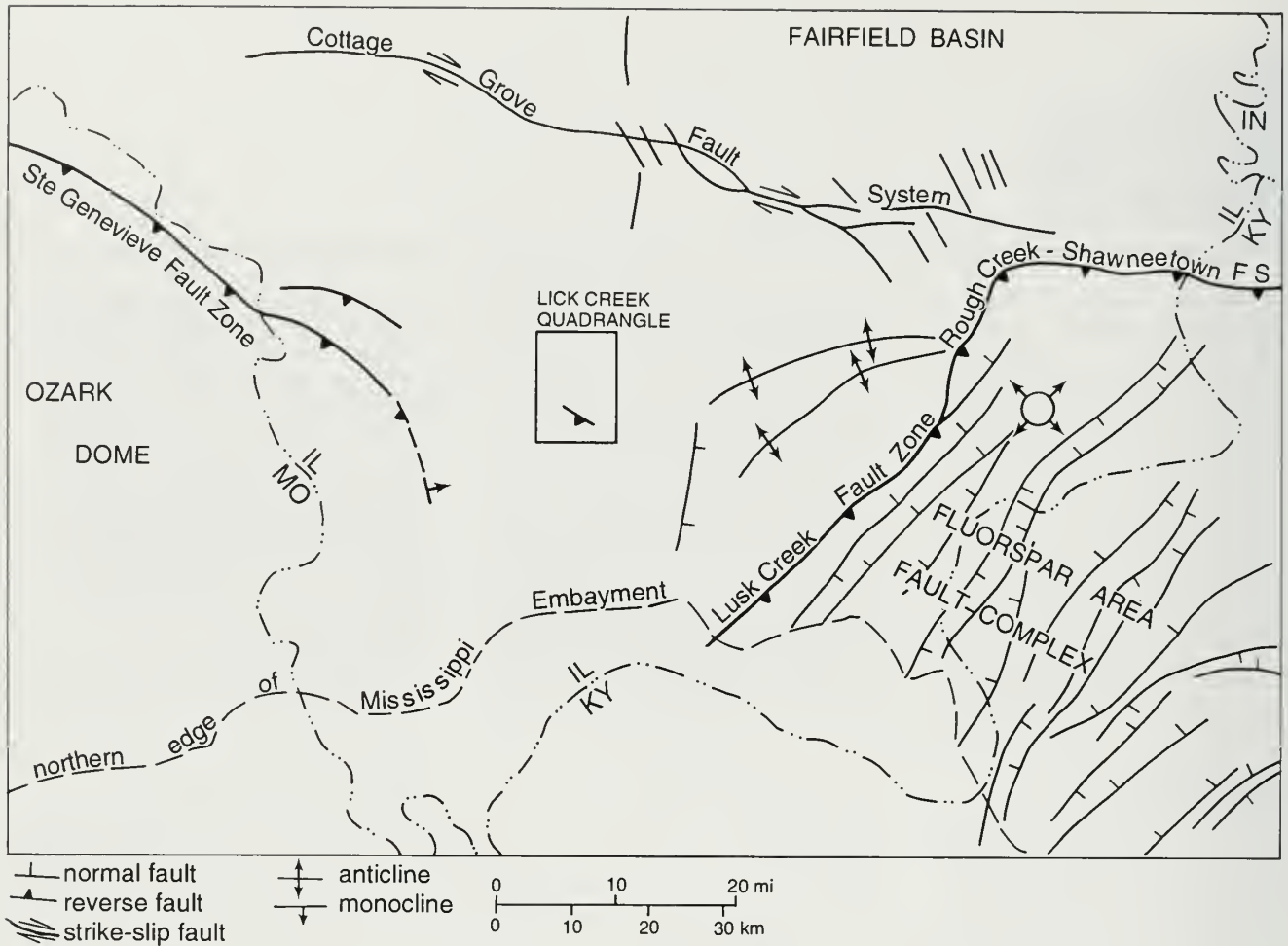


Figure 2 Geologic setting of the study area shows selected structural features.

range of 100°F (38°C), mean temperature of 57°F (14°C), mean annual precipitation of 46 inches, and a growing season of about 190 days (Parks 1975). Most ridge slopes and some ridge tops are wooded, largely in oaks and hickories, along with beech, tuliptree, sugar maple, and white ash and occasional black walnut, butternut, Ohio buckeye, and basswood (Schwegman et al. 1973). Logging is widespread, and timbered areas are rapidly overgrown by brambles, brush, and small trees. Bottomland forests have largely been cleared for agriculture. Many open ridge tops are abandoned cultivated fields converted to pasture. Bottomlands generally are cultivated or converted to pasture by introducing perennial grasses, commonly Johnson grass.

Bedrock mapping in southern Illinois is hampered by deep weathering, dense vegetation, and the thick blanket of loess. Mapping was conducted during the winter, when snakes, ticks, and biting insects are inactive and

vegetation is least obstructive. Even in winter, recently logged areas and overgrown pastures can be nearly impassible. The only rocks that crop out prominently are massive and well indurated sandstones. Limestones weather deeply by solution and crop out only intermittently on south-facing hillsides. Shale, siltstone, thin bedded sandstone, and glacial sediment are generally exposed only in cutbanks of large streams, deep gullies, and artificial exposures such as roadcuts. Geologic contacts commonly must be inferred from float and topography. Descriptions of stratigraphic units are derived in large part from cores drilled specifically for this study.

### General Geologic Setting

The Lick Creek Quadrangle is located near the southern margin of the Illinois Basin, east of the Ozark Dome, and north of the Mississippi Embayment (fig. 2). Paleozoic bedrock strata in the quadrangle dip

gently northeast toward the center of the basin. The study area is a short distance west of the Illinois-Kentucky Fluorspar District, a complexly faulted area dominated by northeast-trending, high-angle normal faults. About 10 miles west of the Lick Creek Quadrangle is the southern terminus of the Ste. Genevieve Fault Zone, which partially separates the Illinois Basin from the Ozark Dome. A zone of high-angle normal and reverse faults, the Ste. Genevieve has undergone at least two episodes of displacement (Nelson and Lumm 1985).

The northern part of the Quadrangle was glaciated during the Illinoian Age of the Pleistocene Epoch. The Lick Creek and adjacent Goreville Quadrangle contain evidence of the southernmost advance of continental ice sheets in North America. Glacial sediments and bedrock throughout the quadrangle are mantled by younger Pleistocene and Holocene loess, alluvium, colluvium, and talus.

**Table 1** Boreholes in the study area

<b>Operator, farm, or lease</b>	<b>Location</b>	<b>ISGS county no. and well type</b>	<b>Deepest formation penetrated and total depth (ft)</b>
<b>Union County</b>			
Nation Oil Co. no. 1 Gray	SE NW SE Sec. 2, T11S, R1E	4 Petroleum test	Ste. Genevieve 1,948
Mitchell no. 1 Fly	NW SW NE Sec. 9, T11S, R1E	5 Petroleum test	Ste. Genevieve 1,728
Skiles Oil Corp. no. 1 Brewer	NW NE NW Sec. 11, T11S, R1E	2 Petroleum test	Ste. Genevieve 1,874
Noella Piacenti	1950' FSL, 2200' FWL, SW Sec. 16, T11S, R1E	20321 Water well	Clore 520
Terry Thorn	NW SE NW Sec. 16, T11S, R1E	20500 Water well	Pope Group 460
John Shewmaker	NW NE SE Sec. 17, T11S, R1E	20501 Water well	Pope Group 520
Soil Cons. Service no. 1 Parks	NE NW SE Sec. 20, T11S, R1E	3 Limestone test	Clore 145
Kent Herbert	NW NW SW Sec. 21, T11S, R1E	20502 Water well	Pope Group 312
Monjeb Minerals no. 1 Richards	NW NW SW Sec. 21, T11S, R1E	20474 Petroleum test	Ste. Genevieve 1,450
Wayside Farms	SW SW NE Sec. 22, T11S, R1E	20322 Water well	Clore 390
John R. Beanland David Suits	NE NW NE Sec. 28, T11S, R1E	186 Water well	Pope Group 740
ISGS COGEOMAP L-3	NE SW SE Sec. 35, T11S, R1E	20851 Stratigraphic test	Menard 266
<b>Johnson County</b>			
Monjeb Minerals no. 1 Throgmorton	SW NE SW Sec. 5, T11S, R2E	20370 Petroleum test	Ste. Genevieve 2,015
Robert Graves	NW SE NW Sec. 30, T11S, R2E	20273 Water well	Kinkaid 230
Adams no. 1 Walker	SW NE SE Sec. 31, T11S, R2E	77 Petroleum test	Golconda 926
ISGS COGEOMAP L-2	800' FNL, 2800' FEL Sec. 31, T11S, R2E	20427 Stratigraphic test	Degonia 264
<b>Williamson County</b>			
ISGS COGEOMAP G-1	SW SW SW Sec. 28, T10S, R2E	23454 Stratigraphic test	Tradewater 300
Carolyn Oil Co. no. 1 Throgmorton	NE SE NW Sec. 29, T10S, R2E	1097 Petroleum test	Ste. Genevieve 2,030
Cantine & Hardin no. 1 Jones Bros.	SE NW SW Sec. 29, T10S, R2E	2013 Petroleum test	Ste. Genevieve 1,991
Hildreth no. 1 Houston	SE NE NE Sec. 29, T10S, R2E	2290 Petroleum test	Ste. Genevieve 2,109

## Previous Geologic Studies

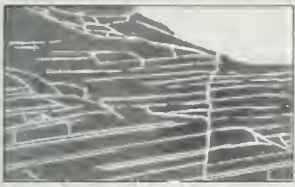
The earliest geological reconnaissance of southern Illinois was performed by the first Geological Survey of Illinois, under the direction of Amos Worthen. In his reports for this survey, Engelmann (1866) described the areal geology of Johnson County and remarked on the topography near Buck Branch. Worthen described the areal geology of Union County (1868) and Williamson County (1875). These reports established the stratigraphic and structural framework of the region and remain useful because they describe many outcrops.

Lamar (1925) mapped and described the geology and mineral resources of the Carbondale 15-minute Quad-

range, whose southeast quarter includes the Lick Creek 7.5-minute Quadrangle. Geology of the area immediately south of the Lick Creek Quadrangle was mapped by S. Weller and Krey (1939) at the scale of 1:62,500. The Goreville Quadrangle to the east (Jacobson 1991), the Makanda Quadrangle to the west (Weibel and Jacobson 1993), and the Bloomfield Quadrangle to the southeast (Nelson 1995) have been mapped at the scale of 1:24,000. The glacial boundary in the Lick Creek Quadrangle and adjacent areas was mapped and discussed by Willman and Frye (1980). Our mapping and interpretation of Quaternary deposits are more detailed and differ from those of Willman and Frye.

## Methodology

Mapping for this study commenced in the spring of 1987 and was completed in the spring of 1988. Outcrop data were recorded in field notes and on topographic maps. Field notes were typed and are available for examination in the library of the ISGS. Subsurface data employed in this study include sample studies and geophysical logs of oil-test holes, drillers' logs of water wells, and core descriptions from three stratigraphic tests drilled by the ISGS (under COGEOMAP). Logs and cores are available for examination in the Geological Records and Samples Library of the ISGS. Wells utilized in this study are listed in table 1.



## STRATIGRAPHY

The Lick Creek Quadrangle is underlain by approximately 14,000 feet of Paleozoic sedimentary rocks that overlie Precambrian crystalline basement rock (Buschbach and Kolata 1991). Only the uppermost 2,600 feet of these strata are exposed at the surface or known from well penetrations within the quadrangle. The oldest unit reached in drilling is the Valmeyeran (Middle Mississippian) Ste. Genevieve Limestone, whereas the oldest outcropping unit is the Chesterian (Upper Mississippian) Menard Limestone. The youngest bedrock in the study area belongs to the upper Morrow through lower Desmoinesian (?) (Pennsylvanian) Tradewater Formation. Plate 1 depicts a stratigraphic column of exposed strata in the quadrangle.

### MISSISSIPPIAN SYSTEM

#### Ste. Genevieve Limestone

Eight wells in the study area have reached the Ste. Genevieve Limestone, and one well (Monjeb Minerals no. 1 Richards) may have completely penetrated the formation and drilled into the underlying St. Louis Limestone (table 1). Geophysical logs and sample studies from the eight wells provide data on the lithology of the Ste. Genevieve Limestone. These well records show the Ste. Genevieve is predominantly limestone, with thin interbeds and lenses of shale and sandstone (fig. 3). The limestone is mostly white to light brownish gray, fine to coarse grained, oolitic and skeletal packstone and grainstone. Interbeds of darker colored, micritic, and very fine to finely crystalline, dolomitic and cherty limestone also are present. Much of the limestone in the upper part of the Ste. Genevieve contains quartz sand; intervals of sandstone as thick as 20 feet are present. Sandstone is light greenish gray, very fine to fine grained, quartzose, glauconitic, and calcareous. Sandstone units are lenticular and cannot be correlated among neighboring wells. Thin

intervals of greenish gray calcareous and silty shale occur in the upper Ste. Genevieve.

The deepest penetration below the top of the Ste. Genevieve was 260 feet in the Monjeb Minerals no. 1 Richards well (table 1). The company sample study indicates that approximately the lower 35 feet of this interval was cherty, dolomitic, micritic limestone, a lithology typical of the St. Louis Limestone. If this lowermost rock is St. Louis, the Ste. Genevieve is about 225 feet thick in the Richards well.

#### Pope Group

The Pope Group (Swann and Willman 1961) comprises alternating carbonate and siliciclastic formations of late Valmeyeran and Chesterian age. In the Lick Creek Quadrangle, the Pope includes formations from the Aux Vases Sandstone at the base to the Kinkaid Limestone at the top (fig. 3). In wells of the study area, thickness of the group ranges from 1,285 to 1,365 feet. Only the upper part of the Menard Limestone and younger formations crop out in the study area. The lower two-thirds of the Pope is known from well records and exposures in adjacent quadrangles.

**Aux Vases Sandstone** Records of eight wells indicate the Aux Vases Sandstone is 21 to 32 feet thick and composed of light greenish gray, very fine grained quartzose, glauconitic, and calcareous sandstone, which grades to sandy limestone. Fossil fragments and oolites are common, and interbeds of greenish gray, calcareous and silty shale also are present.

**Renault Limestone** Much of the Renault Limestone is lithologically similar to the Ste. Genevieve: light colored oolitic and skeletal grainstone and packstone containing quartz sand, and lesser amounts of darker micritic to finely crystalline, dolomitic limestone. The upper part of the Renault is commonly pink or red, and contains reddish brown, hematitic oolites or pellets. Thin

shale interbedded in the Renault is variegated red, green, and gray, and occurs in intervals that are thinner than 5 feet. Eight well records indicate the Renault is 42 to 70 feet thick.

#### Yankeetown Formation and Downeys Bluff Limestone

Overlying the Renault Limestone is a complex succession of interbedded limestone, sandstone, and shale, equivalent to the Yankeetown Formation and Downeys Bluff Limestone (fig. 3). This interval cannot be subdivided in the Lick Creek Quadrangle. Thickness of the interval in eight wells ranges from 92 to 137 feet.

In general, sandstone occurs near the base of the Yankeetown–Downeys Bluff interval, whereas intercalated shale and limestone, along with minor sandstone, occur in the upper part. Sandstone is light greenish gray to light reddish gray, very fine to fine grained, glauconitic, and calcareous. Shale is variegated in shades of gray, green, red, purple, and yellow. Much of it is calcareous and contains abundant marine fossils, largely bryozoans and echinoderm fragments. Limestone is commonly silty and sandy and varies from oolitic and crinoidal grainstone to dolomitic lime mudstone. Pink to red crinoid fragments and abundant chert in limestone near the top of the interval are characteristic of the Downeys Bluff Limestone in southern Illinois.

**Bethel Sandstone** In the Lick Creek Quadrangle, the Bethel Sandstone is thin and lenticular and composed of fine to medium grained, calcareous sandstone and sandy, crinoidal limestone with interbeds of dark gray shale. It is absent in three out of eight wells, less than 5 feet thick in three wells, and 14 feet thick in one well.

**Ridenhower Shale** The Ridenhower Shale is an interval of shale containing thin limestone interbeds (fig. 3) and is 34 to 83 feet thick. Shale is olive gray to dark gray, soft,

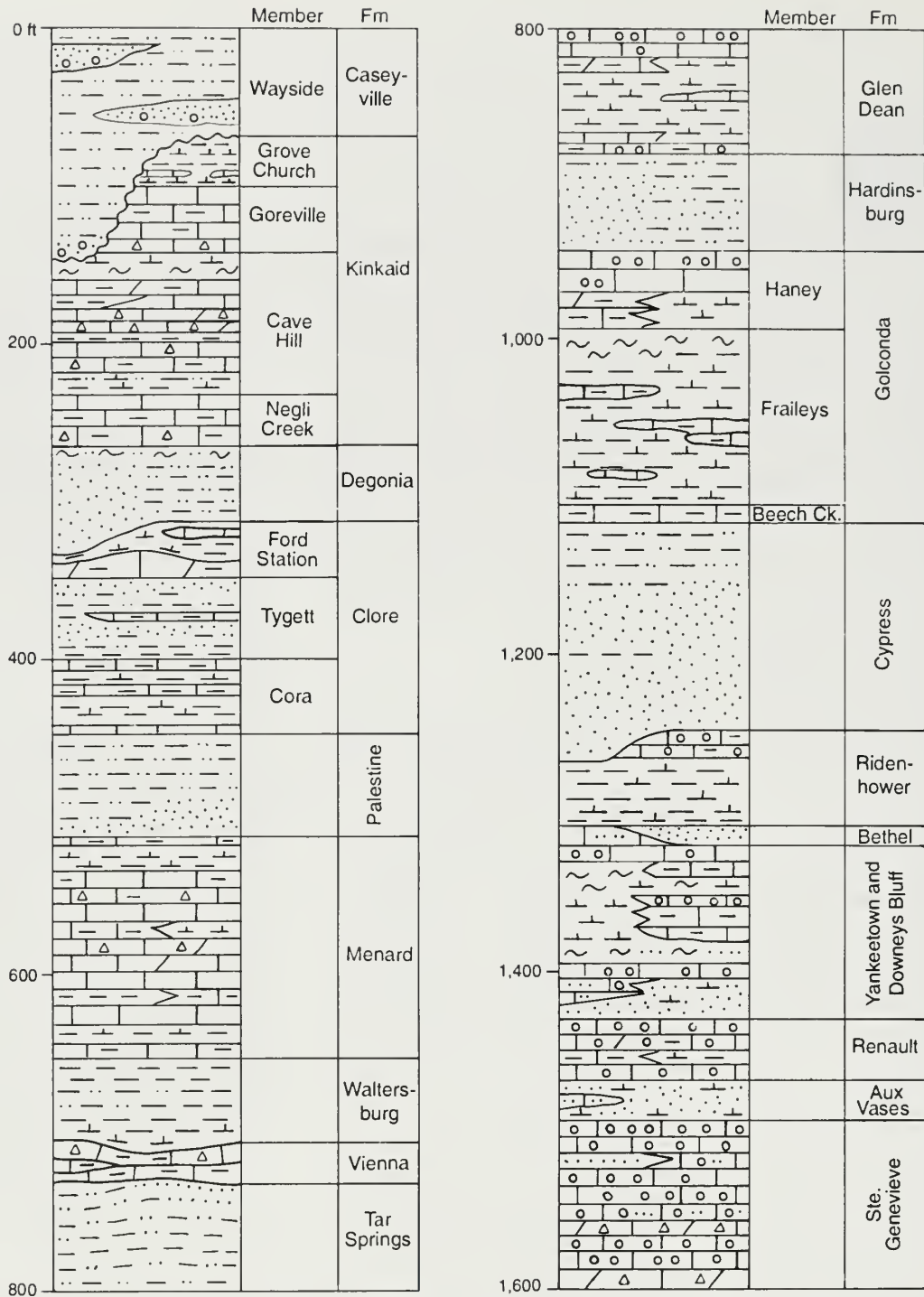


Figure 3 Generalized stratigraphic column of the Pope Group (Mississippian) and enclosing strata.

partly silty, calcareous, and very fossiliferous; in the lower Ridenhower, it tends to be dark and sideritic. Ridenhower shale has lower electrical resistivity than most other shales of the Pope Group. Limestone is largely brownish gray, argillaceous, crinoidal and oolitic grainstone. The thickest limestone beds (up to 15 feet) are at or near the top of the Ridenhower.

**Cypress Sandstone** The Cypress Sandstone, penetrated in eight wells, is 106 to 165 feet thick. The lower two-thirds of the Cypress is almost entirely sandstone: white to light gray, fine to medium grained quartz arenite. Some sandstone is calcareous and contains marine fossil fragments. Thin interbeds of olive gray to reddish gray, calcareous shale occur in some wells. The uppermost

10 to 50 feet of the Cypress is composed mostly of dark gray, silty shale containing carbonaceous debris and thin coal (fig. 3).

**Golconda Formation** The Golconda Formation is a 133- to 204-foot-thick interval of limestone and shale, penetrated by nine wells. Three members can be recognized: (1) the thin basal Beech Creek Lime-

stone Member at the bottom, (2) the Fraileys Shale Member, and (3) the Haney Limestone Member at the top (fig. 3).

The Beech Creek is 2 to 10 feet thick in eight out of nine wells and consists of dark brownish gray, fine grained, argillaceous, dolomitic, crinoidal wackestone and packstone. In the Monjeb no. 1 Richards well, the Beech Creek is unusually thick (33 feet) and consists of light brown, micritic to fossiliferous limestone that is sandy at the base.

The Fraileys is 65 to 140 feet thick shale with occasional interbeds of limestone. Most of the shale is medium to dark gray, sideritic, calcareous, and fossiliferous. Near the top of the member is an interval of variegated greenish gray and red claystone. Limestone beds in the Fraileys are mostly thinner than 5 feet and are argillaceous crinoidal wackestone and grainstone.

The Haney Limestone is 13 to 60 feet thick and varies from light brownish gray, oolitic grainstone and crinoidal-bryozoan wackestone and packstone to dark brownish gray, argillaceous and cherty, dolomitic lime mudstone. Laminae and interbeds of gray, calcareous, fossiliferous shale less than 5 feet thick are present.

**Hardinsburg Formation** The Hardinsburg Formation is a siliclastic unit 22 to 70 feet thick. Sandstone, siltstone, and shale occur in varying proportions. Sandstone is white to light gray, very fine to fine grained quartz arenite. Siltstone and shale are medium to dark gray and greenish gray, laminated, and generally noncalcareous. The Hardinsburg is almost entirely sandstone in the Adams no. 1 Walker well; but in other wells in the quadrangle, 50% to 100% of the formation is shale and siltstone.

**Glen Dean Limestone** The Glen Dean Limestone is an interval of limestone and shale 60 to 95 feet thick, as shown by the logs of nine wells. A thin lower limestone, a medial shale, and a moderately thick upper limestone are consistently present. The lower limestone (4 to 15 feet thick) is brownish gray, dolomitic, oolitic, and crinoidal packstone. The medial shale is 24 to 49 feet thick and is olive gray, greenish gray, and dark gray, soft, calcareous clay shale containing abundant bryozoans. Red shale was reported in the sample log of one well. The upper lime-

stone is 17 to 41 feet thick and lithologically resembles the lower limestone. It is largely coarse crinoidal and oolitic grainstone and packstone, but wackestone and dolomitic lime mudstone also are present.

**Tar Springs Formation** The Tar Springs is 70 to 99 feet thick and composed of 80% to 100% interlaminated shale and siltstone (fig. 3). For this reason, the name Tar Springs Formation is used instead of Tar Springs Sandstone. Shale and siltstone are medium to dark gray and olive gray, fissile, and noncalcareous. In several wells, black carbonaceous shale and thin coal occur near the top of the Tar Springs. Sandstone, where present, is near the top of the formation and thinner than 20 feet. Like other sandstone of the Pope Group, this is white to light gray, very fine to fine grained quartz arenite.

**Vienna Limestone** The Vienna Limestone is 7 to 33 feet thick and is mostly medium to dark brownish gray, argillaceous, and silty lime mudstone containing scattered bioclasts and much chert. Lighter colored, sandy, skeletal, and oolitic packstone and grainstone occur in the upper part of the Vienna in some wells.

**Waltersburg Formation** The Waltersburg Formation is 38 to 60 feet thick and composed dominantly of medium to dark gray, olive gray, and greenish gray clay shale and silty shale. Shale contains laminae or thin interbeds of siltstone and very fine grained, dark gray, argillaceous sandstone. Flakes of carbonaceous plant remains occur in the shale, and coal was reported near the top of the Waltersburg in one sample log. The shale also contains marine fossils, including echinoderm and bryozoan fragments.

**Menard Limestone** The oldest bedrock unit exposed in the quadrangle is the Menard Limestone, an interval of interbedded limestone and shale (fig. 3). The Menard was named by S. Weller (1913) for exposures at the quarry of the Menard Correctional Center at Chester, Randolph County, southwestern Illinois. Swann (1963) divided the Menard in southern Illinois into three members (Walche, Scottsburg, and Allard), but these members are not distinguishable in the Lick Creek Quadrangle.

The Menard crops out along Bradshaw Creek at the southwest

corner of the quadrangle. Exposures consist of isolated ledges of limestone, many of which have been displaced downslope by slumping or soil creep. Springs and small sinkholes are common in the area of Menard outcrops. Most information on the lithology of the Menard has been taken from well records, which indicate the Menard is 132 to 147 feet thick, and approximately the upper 50 to 60 feet crops out within the quadrangle.

Limestone, the dominant lithology, is medium to dark gray and generally weathers to smooth, light gray surfaces. Most of it is fossiliferous lime mudstone and fine to coarse grained skeletal wackestone that contains abundant pelmatozoan fragments. Other fossils include bryozoans, brachiopods, and a few pelecypods (razor clams). Bedding at outcrops ranges from about ½ to 2 feet thick. Bedding surfaces are wavy or hummocky and are separated by argillaceous partings. The limestone contains interbeds of medium gray or olive gray to black, slightly to highly fissile shale that is partly calcareous and fossiliferous. Shale interbeds range from a fraction of an inch to about 15 feet thick.

The uppermost part of the Menard is composed largely of shale with thin interbeds of limestone. In the core from COGEOMAP borehole L-3, the uppermost 25 feet of the Menard is largely medium dark gray to black, fissile, calcareous clay shale (fig. 4). The shale contains argillaceous limestone lenses and is moderately to abundantly fossiliferous (brachiopods, bryozoans, pelmatozoans). Limestone interbeds are medium to dark gray, argillaceous, fossiliferous (brachiopods and pelmatozoans) lime mudstone. The thickest limestone bed in the core is about 3 feet thick.

Contact with the overlying Palestine Formation was mapped at the highest exposure of limestone below sandstone float from the Palestine. Well records indicate this contact is sharp or rapidly gradational. The contact is sharp and probably disconformable in the core from COGEOMAP borehole L-3.

**Palestine Formation** The siliclastic unit overlying the Menard Limestone in southern Illinois was originally named the Palestine Sandstone for exposures in Palestine Township, Randolph County, southwestern Illinois (S. Weller 1913). This report uses the term *formation*

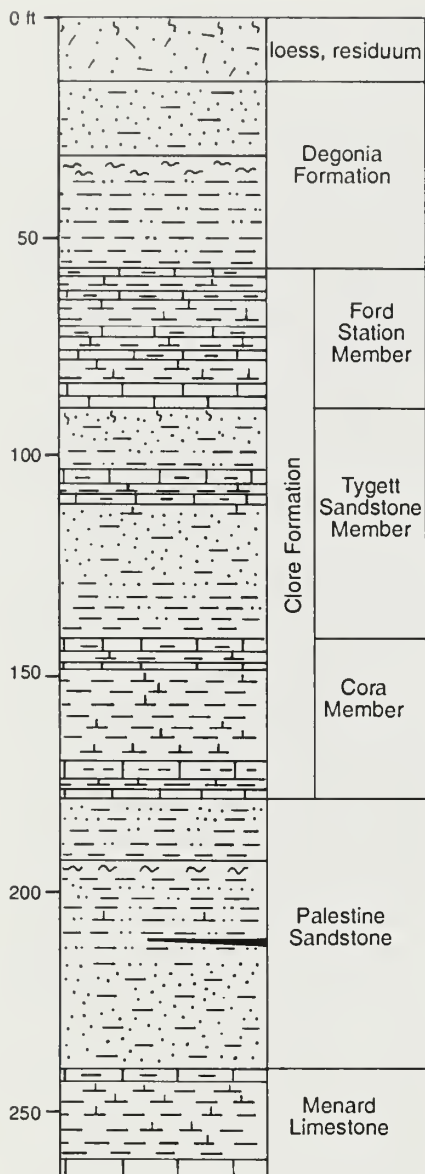


Figure 4 Graphic column of COGEO- MAP borehole L-3. This core contains the reference section of the Tygett Sandstone Member of the Clore Formation.

rather than *sandstone* because shale and siltstone are major constituents in the Lick Creek Quadrangle.

In the quadrangle, the Palestine is 40 to 67 feet thick and crops out in a narrow belt northeast of Bradshaw Creek near the southwest corner of the quadrangle, and also along a south-flowing tributary of Bradshaw Creek in the SE, Section 3, T12S, R1E. Most Palestine outcrops consist of sandstone that forms small, discontinuous ledges. Shale and siltstone of the Palestine are exposed only locally in the banks of streams. Well records, particularly the core from COGEO- MAP borehole L-3,

supplement observations from the meager outcrops.

Sandstone of the Palestine is olive gray to light brown and dark gray green and weathers light yellowish brown, to orange brown or brown. It is fine grained (rarely medium grained) and composed of sub-rounded, well sorted quartz sand with a few percent mica, feldspar, and dark grains. Carbonized plant fragments are locally abundant, ripple marks are common, and bedding ranges from 0.1 to 1 foot thick. At the top of the formation is greenish gray to brownish gray calcareous siltstone that contains abundant carbonaceous plant fragments and interbeds of fissile, gray, noncalcareous shale.

Siever (1953) reported that quartz is the dominant constituent of sandstone from the Palestine, with subordinate clay, carbonate, and chert and traces of feldspars and heavy minerals. Such composition is typical for sandstone of the Pope Group (Potter 1963). These sandstones are quartz arenites and sublitharenites. Well records indicate that the Palestine is lithologically variable. In some wells, the formation is entirely shale and siltstone; but in others a sandstone up to 20 feet thick occurs near the base.

In the core from COGEO- MAP borehole L-3 (fig. 4), the Palestine is 60.8 feet thick and consists of interbedded and interlaminated sandstone and shale. Sandstone in the core is light gray, very fine grained, partly calcareous quartz arenite; shale is dark gray, well indurated, silty, and noncalcareous. Ripple laminations, horizontal shale laminations, small load casts, and slump structures are common throughout the core, and several burrowed intervals are present. Near the middle of the formation is a thin, dull, argillaceous coal, which overlies a siltstone containing plant fossils and plant rootlets. Overlying the coal is mudstone that contains limestone nodules and plant fossils. A layer of fragmented pelecypods occurs about 20 feet below the top of the Palestine.

Contact between the Palestine and the overlying Clore Formation is not exposed in the quadrangle. Contact was mapped in the field at the lowest exposure of limestone or calcareous shale typical of the Clore. Well records, including the core from COGEO- MAP borehole L-3, indicate a sharp but conformable contact.

**Clore Formation** The succession of interbedded shale, limestone, and sandstone overlying the Palestine Formation is called the Clore Formation. The Clore was named by S. Weller (1913) for exposures near Clore School, Randolph County, southwestern Illinois. Swann (1963) divided the Clore into three members: (1) the lower Cora Member of shale with thin limestone beds, (2) the Tygett Sandstone Member of sandstone, siltstone, shale, and thin limestone beds, and (3) the upper Ford Station Member of interbedded limestone and shale. All three members of the Clore are present in the Lick Creek Quadrangle. For this survey, the Cora was mapped separately; the Tygett and Ford Station Members were combined as one unit because the contact between the members was not easily mappable. A limestone bed in the Tygett Member is shown on the geologic map (Weibel and Nelson 1993).

The Clore crops out in the southeastern and south-central part of the quadrangle, from Bradshaw Creek eastward. The formation is 110 to 138 feet thick, as measured on the logs of six wells.

**Cora Member** Swann (1963) proposed the name "Cora Limestone Member" for the lowest part of the Clore Formation, as exposed near Cora, Jackson County, southwestern Illinois. The member is largely limestone in its type area; but in the Lick Creek Quadrangle, the Cora consists of approximately two-thirds shale and one-third limestone. Thus, we refer to the unit as the Cora Member.

Shale of the Cora is medium olive to greenish gray to dark gray, calcareous to noncalcareous, and generally fissile. It is mostly clay shale, but some silty shale and a little siltstone are present. Siltstone is greenish gray to medium gray, laminated to thinly bedded, and partly calcareous. Silty beds occur mostly in the lower part of the member.

Limestones of the Cora are argillaceous and medium gray to dark gray, weather light olive gray to light brown, and tend to spall into thin, irregular layers as they weather and to break into small, flat chips when hammered. Limestones consist of fossiliferous lime mudstone and fine to medium grained skeletal wackestone, containing numerous whole fossils. Fossils of the Cora include brachiopods (compositids, spiriferids, derbyids, and produc-



tids), bryozoans, gastropods, pelmatozoans, and rare orthoconic cephalopods. Fossils from the Clore listed by Lamar (1925) are mostly, if not entirely, from the Cora Member.

The larger proportion of shale, more argillaceous limestones, and greater abundance of whole fossils distinguish the Cora from the Menard Limestone. Limestone beds in the Cora rarely exceed 3 feet, whereas those of the Menard commonly are 10 feet or more thick. Limestone beds of the Cora crop out only in deep ravines and stream banks, and limestone blocks on hillsides generally have been displaced by slumping and soil creep.

In the core from COGEOMAP borehole L-3, the Cora is dominated by ½- to 7-foot-thick intervals of shale that contain interbedded limestone (fig. 4). The shale is mostly greenish gray to medium dark and dark gray, laminated, calcareous, and fossiliferous. Some shale is black and noncalcareous and contains laminae of micaceous siltstone, horizontal burrows, and siderite layers. Brachiopods, bryozoans, and echinoderm fragments are common. The numerous thin interbeds of limestone that range from several inches to more than 4 feet thick are medium gray to dark gray, argillaceous lime mudstone with fossil fragments and shale laminae. Whole and fragmentary brachiopods, fenestrate and ramose bryozoans, gastropods, and pelmatozoans are common; several coquina beds are present.

In the Lick Creek Quadrangle, the Cora is 55 to 75 feet thick in outcrops and 38 to 60 feet thick in wells. Thickness was measured from the highest occurrence of limestone or calcareous shale to the lowest. Variance between surface and subsurface data may reflect imprecise placement of member contacts because of poor exposures. Some shale of the uppermost Palestine Formation or lowermost Tygett Sandstone Member may have been included with the Cora on the geologic map (Weibel and Nelson 1993).

Contact of the Cora with the overlying Tygett is conformable and either sharp or gradational through a few inches, from limestone of the uppermost Cora to clay shale and silty shale of the Tygett.

**Tygett Sandstone Member** The Tygett Sandstone Member, as named by Swann (1963), is the middle clastic portion of the Clore Formation.

The type section is near Tygett School on the south side of Bradshaw Creek in the Makanda Quadrangle, about 2 miles west of the Lick Creek Quadrangle (near center, NE NW, Sec. 24, T11S, R1W, Union County). Previous geologists mapped the Tygett in formations other than the Clore. Lamar (1925) mapped the Tygett as part of the Degonia Formation in most of the Lick Creek Quadrangle, but southeast of Lick Creek village he mapped some Tygett as part of the Palestine. South of the Lick Creek Quadrangle, S. Weller and Krey (1939) mapped the Tygett in the Degonia Formation.

The Tygett Member logically should include all sandstone in the middle part of the Clore Formation. Swann (1963), however, designated only the lower of the two sandstones as the Tygett at the type section, and placed the upper sandstone, about 5 feet thick, in the Ford Station Member. As the upper sandstone is traced eastward, it becomes thicker in places than the lower sandstone. In the Lick Creek Quadrangle, the upper and lower sandstones both are 20 to 40 feet thick, separated by 10 feet or less of shale and limestone.

The Tygett Sandstone Member is therefore revised to include both upper and lower sandstones, along with the thin intervening shale and limestone. The Ford Station Member is restricted to limestone and shale overlying sandstone of the Tygett. Sandstone does not occur in the Ford Station at its type section (Swann 1963, p. 42).

A subsurface reference section for the Tygett is hereby designated in the interval from 88.3 to 141.5 feet in the core from COGEOMAP borehole L-3 (fig. 4). The core is stored in the samples library of the ISGS under sample number C-13460.

In outcrops in the Lick Creek Quadrangle, the Tygett is about 70 to 80 feet thick and consists of two relatively thick, upward-coarsening siliciclastic units separated by a thin interval of intercalated limestone and shale. The siliciclastic intervals both grade upward from clay shale or silty shale at the base to sandstone at the top. Basal shales are medium gray, olive gray, brownish gray, fissile, and noncalcareous. Laminae and thin interbeds of light gray siltstone to very fine sandstone become thicker and more numerous upward. Fine grained siliciclastic rocks are planar laminated and ripple laminated. Sandstones in the

Tygett are very fine to fine grained, argillaceous quartz arenites; generally, they are light gray to light brownish gray and weather yellowish brown. Quartz grains are well sorted and subrounded, and dark mineral grains are present. Tygett sandstones are largely thinly bedded, but thick bedded sandstones occur locally in the upper parts of both sandstones. Current and interference ripple marks, along with vertical and horizontal burrows and trails, are common in the thin bedded sandstone. The trace fossil *Rhizocorallium* occurs near the top of the lower Tygett sandstone. Stigmarian root casts are present at the tops of both sandstones.

A middle limestone in the Tygett was previously recognized southeast of the Lick Creek Quadrangle, in the Waltersburg Quadrangle (Weibel et al. 1991), the Glendale Quadrangle (Devera 1991), and the Bloomfield Quadrangle (Nelson 1993). In the Lick Creek Quadrangle, the middle limestone interval of the Tygett is 2 to 10 feet thick and consists of a single limestone bed or two or three limestone beds separated by layers of medium to dark brownish gray, fissile clay shale. Tygett limestone resembles limestone of the Cora Member: argillaceous lime mudstone and skeletal wackestone with abundant pelmatozoan and brachiopod fragments. Coal fragments less than 0.5 inch in diameter occur in the limestone. Good exposures of the medial Tygett limestones occur in ravines in the NE, Section 32, and the NW, Section 33, T11S, R1E, and in Sections 1, 2, and 3 of T12S, R1E.

In the Lick Creek Quadrangle, the Tygett is 28 to 80 feet thick. Well records indicate that the Tygett thins to the north and that the middle limestone unit is absent in the northern part of the quadrangle. Contact with the overlying Ford Station Member is sharp and possibly disconformable. Fossil root casts at the top of the Tygett are evidence for subaerial exposure.

**Ford Station Member** The name "Ford Station Limestone Member" was proposed by Swann (1963) for the upper part of the Clore exposed near Ford Station in Randolph County, southwestern Illinois. Because the unit contains roughly equal proportions of shale and limestone, the name is shortened to "Ford Station Member" in this report.

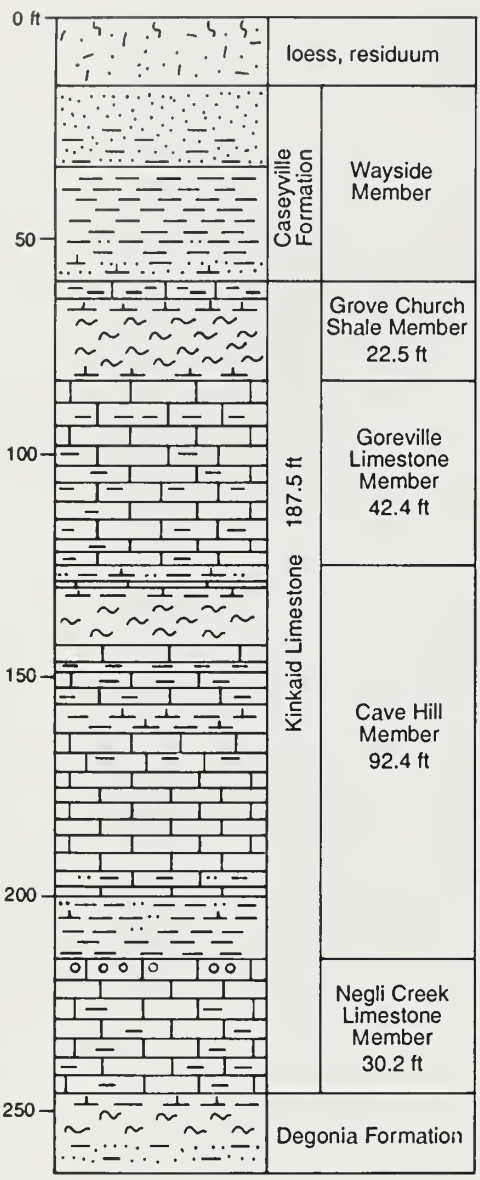


Figure 5 Graphic column of COGEO-MAP borehole L-2.

A massive 5-to-16-foot-thick limestone bed occurs at or near the base of the Ford Station Member in this quadrangle and appears to be continuous across several adjacent quadrangles. The limestone is light to dark gray, slightly dolomitic lime mudstone to skeletal wackestone, containing fine to coarse echinoderm and brachiopod shell fragments. Good exposures of this limestone occur along Bradshaw Creek at the west edge of the quadrangle (SW SE, Sec. 29, and NW NE, Sec. 32, T11S, R1E).

The upper part of the Ford Station consists of alternating beds from limestone and shale, as in the core from COGEO-MAP borehole L-3 (fig. 4). Limestones are light gray to dark gray to brownish gray mud-

stones to wackestones that contain fine to coarse grained pelmatozoan and brachiopod fragments. Some of the limestone beds are dolomitic and argillaceous, containing interbeds and inclusions of shale. Shale is of two types: a partly calcareous and fossiliferous, poorly indurated, dark greenish gray to dark olive gray to black, poorly to moderately fissile clay shale; and a partly noncalcareous, micaceous, moderately indurated, dark gray, and fissile clay shale to finely silty shale.

The Ford Station is 32 feet thick in COGEO-MAP borehole L-3 and 20 to 45 feet in other boreholes in the quadrangle. Contact with the overlying Degonia Formation is sharp (as shown in a core from COGEO-MAP borehole L-3) and apparently disconformable in the few places where it is visible. A good exposure occurs along a small ravine between Drapers Bluff and Lick Creek (SW SE SE, Sec. 36, T11S, R1E).

**Degonia Formation** This siliclastic unit overlying the Clore Formation was originally named the "Degonia Sandstone" by S. Weller (1920) for outcrops in Degonia Township, Jackson County, southwestern Illinois. Swann (1963) called the unit the Degonia "Sandstone" or "Shale." In the Lick Creek Quadrangle, it consists of various lithologies and therefore is named the Degonia Formation.

The Degonia consists of interbedded shale, siltstone, and sandstone. Shale is mostly gray to brownish gray, weathers brown, and is fissile, noncalcareous, and poorly indurated. Siltstone is medium gray to greenish gray, noncalcareous, and moderately indurated. Sandstone is argillaceous, very fine to fine grained, and light gray, light brown, or greenish gray, weathering orange brown to gray brown. The sand is mostly subrounded, well sorted quartz grains, with a few percent of dark minerals. Locally the sandstone contains scattered shale clasts. Beds are irregular and 0.1 to 1 foot thick. Ripple marks and horizontal laminations are present; burrows are common. Plant fossils and a thin carbonaceous shale (almost a coal) occur in a gully in the NE SE, Section 35, T11S, R1E. Probable root impressions occur in the claystone below this shale. In outcrops in the SE, Section 36, T11S, R1E, shale coarsens upward to siltstone. Along the drainage that trends east from the center of Section 35, the Degonia consists of sandstone

near the bottom and top, with finer grained strata between.

The lower 41.5 feet of the Degonia was cored in COGEO-MAP borehole L-3 (fig. 4). The basal 20 feet consists of dark gray noncalcareous shale with fine grained sandstone laminae and burrow fillings. The overlying 4.5 feet of strata are gray to brown, carbonaceous claystone. The upper 17 feet of the Degonia in the core consists of very fine grained, yellow brown, quartzose sandstone.

Variogated mudstone 10 to 15 feet thick occurs at the top of the Degonia in the study area and elsewhere. Typically, medium to dark gray, poorly laminated, silty shale at the base grades upward to multi-hued (yellow, gray, and maroon) noncalcareous, blocky claystone. This mudstone was cored in COGEO-MAP borehole L-2 (fig. 5). Variogated claystone of the upper Degonia is persistent throughout southern Illinois (Swann 1963).

The Degonia Formation abruptly thickens westward and changes facies near the west edge of the Lick Creek Quadrangle. Here, along Bradshaw Creek, in the SE, Section 29, T11S, R1E, is the easternmost occurrence of thick bluff-forming sandstone in the Degonia outcrop belt in Illinois. To the west, similar thick sandstones are common in the Degonia. In the quadrangle, the sandstone is white to light gray and brown, very fine to fine grained, well sorted quartz arenite. Bedding is mostly 0.2 to 0.5 foot thick, but several beds are 2 feet thick. Low-angle crosslamination is common, and foreset laminae dip south-southeast to southwest. The sandstone thickens from less than 10 feet to more than 40 feet within a lateral distance of about 1/4 mile.

The Degonia thickens westward on the outcrop from about 40 feet to 80 feet. Data from six wells indicate the Degonia is 48 feet to 78 feet in the northwest quarter of the quadrangle.

The contact with the overlying Kinkaid Limestone is sharp and undulatory and may be disconformable. In most places, the limestone overlies variogated claystone, but locally the claystone is absent (eroded?), and the Negli Creek Limestone Member directly overlies sandstone or siltstone of the Degonia.

**Kinkaid Limestone** The uppermost Mississippian formation in southern Illinois is the Kinkaid

Limestone, named by S. Weller (1920) for exposures along Kinkaid Creek in Jackson County, southwestern Illinois. As originally defined, the Kinkaid included all strata from the top of the Degonia Formation to the base of the Pennsylvanian System. Swann (1963) redefined the Kinkaid as containing three members: (1) the Negli Creek Limestone Member at the base, (2) the Cave Hill Shale Member, and (3) the Goreville Limestone Member at the top. Shale overlying the Goreville was assigned by Swann to a new formation, the Grove Church Shale. However, Nelson et al. (1991) revised the Grove Church back to a member of the Kinkaid Formation because the Grove Church is too thin and discontinuous to be mapped as a separate formation at scales of 1:24,000 or smaller. Since the Grove Church is present but unmappable in the Lick Creek Quadrangle, this report also groups it in the Kinkaid.

In southern Illinois, the upper part of the Kinkaid was eroded extensively prior to deposition of Pennsylvanian sediments. Consequently, the Grove Church Member is absent in much of the Lick Creek Quadrangle, and locally the Goreville Member is also missing. The Kinkaid ranges in thickness from about 110 feet near the center of Section 25, T11S, R1E, to 187.5 feet in COGEO-MAP borehole L-2 (fig. 5).

The Kinkaid underlies steep slopes below the Pennsylvanian escarpment from the southeast corner to the central west edge of the quadrangle. West and northwest of Lick Creek village, the Kinkaid surrounds several outliers of Pennsylvanian strata but is commonly covered by talus from overlying sandstones. The extensive talus prevents accurate placement on the geologic map of contacts between members of the Kinkaid.

### *Negli Creek Limestone Member*

Malott (1925) proposed the name "Negli Creek Limestone" as a formation for limestone exposed along Negli Creek, Perry County, southern Indiana. Swann (1963) revised the Negli Creek to a member. The Negli Creek is one of the most reliable marker units in the Pope Group because it is highly consistent in thickness and lithology throughout southern Illinois (except where eroded beneath Pennsylvanian rocks). In the Lick Creek Quadrangle, the Negli Creek is readily recognized. Good exposures occur on the east side of

Lick Creek in the NW, Section 36, T11S, R1E, and in an abandoned quarry in the SE, Section 20, T11S, R1E.

The Negli Creek is a limestone unit containing a few partings and thin interbeds of shale. The limestone is medium to dark gray and mostly weathers gray to brownish gray. Locally, dolomitic layers weather yellowish orange. Texturally, the limestone ranges from fossiliferous lime mudstone to coarse grained skeletal packstone and grainstone, but it is mostly lime mudstone and wackestone. Beds range from 0.2 to 3 feet thick and are hummocky. Wavy shale partings and interbeds occur throughout the member but are most common near the base. The thickest shale interval observed was about 2 feet thick; most are much thinner. Shale is non-calcareous, dark gray, and blocky to fissile. Irregularly shaped, gray to black chert layers and nodules are common in the limestone beds.

Fossils are found throughout the Negli Creek and include brachiopods, bryozoans, solitary rugose corals, ostracodes, endothyrid foraminifera, and pelmatozoan fragments. Large bellerophonid gastropods and *Girovanelia* oncoids, when found together, are diagnostic for the lower part of the Negli Creek. Light colored, fine to coarse grained crinoidal or skeletal packstone and grainstone occur in places at the top of the member. Glauconite grains, small dolomite rhombs, and oolitic limestone occur in the core from COGEO-MAP borehole L-2 (fig. 5). Pelmatozoan fragments, brachiopods, bryozoans (fenestrate, ramose, and fistuliporid), foraminifera, and trilobites occur in the upper Negli Creek.

Data from seven boreholes indicate that the Negli Creek is 30 to 32 feet thick. Complete outcrop exposures of the member were not found in the study area. Contact with the overlying Cave Hill Member is sharp but probably conformable.

***Cave Hill Member*** Swann (1963) defined the Cave Hill Shale Member based on exposures in a quarry on Cave Hill in Saline County, southern Illinois, where the unit is largely shale. In the Lick Creek Quadrangle, the Cave Hill consists largely of limestone, with shale/claystone intervals at the base and the top. Thus "shale" is dropped from the name of the member in this report. The best exposure of the Cave Hill in the quad-

rangle is in a quarry in the NE, Section 29, T11S, R1E. Good exposures occur along the large ravine in the NW, Section 31, T11S, R2E. Complete or nearly complete exposures are present in quarries just southeast of the study area in the Goreville and Vienna Quadrangles (fig. 6). These exposures and data from seven wells indicate that the Cave Hill is 83 to 92 feet thick in the report area.

At the base of the Cave Hill is an interval of 12 to 16 feet of greenish gray to bluish gray and dark gray clay shale to silty shale. The calcareous, soft, and fissile shale contains numerous fenestrate bryozoans, brachiopods, pelecypods, pelmatozoans, gastropods, and pelmatozoan fragments. In the core from COGEO-MAP borehole L-2 (fig. 5), the upper part of this shale is silty and contains both plant fossils and marine invertebrates.

The middle part of the Cave Hill is largely limestone with a few shale interbeds and is 55 to 60 feet thick (figs. 3, 5, 6, and 7). The core from COGEO-MAP borehole L-2 (fig. 5) and sections measured in quarries indicate that the detailed stratigraphic succession in the middle Cave Hill is consistent throughout the quadrangle. At the bottom is medium to dark gray lime mudstone to fine grained skeletal wackestone and packstone in beds 0.2 to 3 feet thick. Thin interbeds of dark gray, calcareous shale are numerous. This limestone intertongues with the underlying shale at the Southern Illinois Stone Company's quarry in the Vienna Quadrangle (fig. 6, column C). Above the base, the middle Cave Hill is mostly dense lime mudstone that breaks with conchoidal fractures and contains numerous layers and lenses of dark gray to black chert. At the Southern Illinois Stone Company's quarry, some of this limestone contains fine horizontal to slightly undulating laminations (fig. 8). Petrographic study indicates that the laminations are graded and the micrite is partially dolomitized. The middle Cave Hill also contains dysmicrite—a lime mudstone containing spar-filled veins and cavities that probably reflect shrinkage of the sediment. The upper part of the middle Cave Hill consists of limestone that varies from lime mudstone to medium grained skeletal grainstone. Crossbedded grainstone occurs in the quarry in Section 29, T11S, R1E (fig. 6, column A). At the top of the middle Cave Hill is 5 to 10

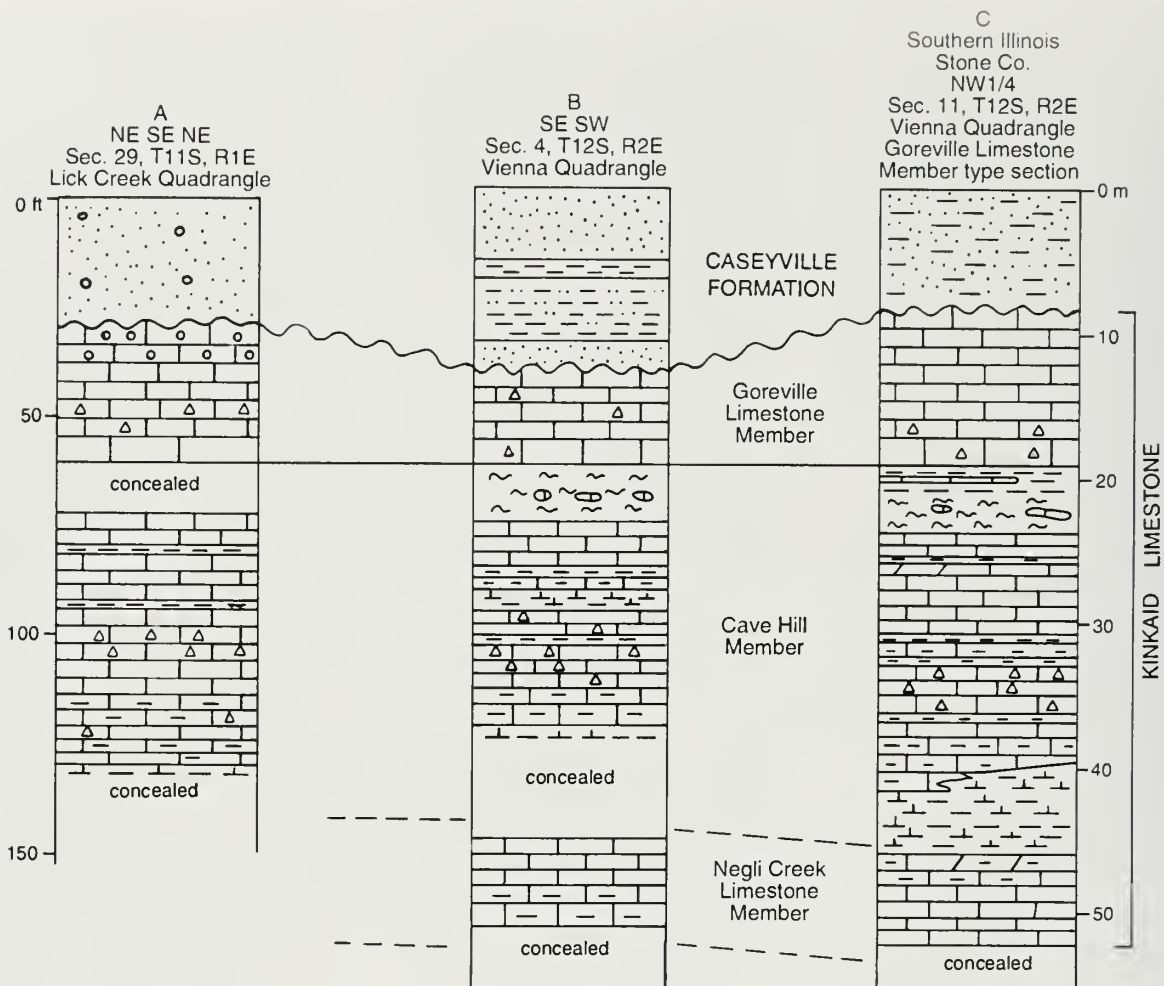


Figure 6 Measured sections of Kinkaid Limestone from quarries.

feet of light gray, nodular-bedded lime mudstone containing numerous streaks and inclusions of green clay.

The upper part of the Cave Hill Member consists of a 13- to 18-foot-thick interval of claystone, shale, and thin limestone beds (figs. 3, 5, 6, and 9). The mottled and variegated claystone is greenish gray, brick red, and ochre. Irregular masses of yellowish gray limestone or dolomite are common in the claystone. The claystone is overlain by dark gray, calcareous, well laminated shale that is interbedded with dark gray, argillaceous lime mudstone, in which myalinid pelecypods and plant fragments are abundant.

#### Goreville Limestone Member

The Goreville Limestone Member was named by Swann (1963) for exposures in the Southern Illinois Stone Company quarry south of Goreville, just southeast of the Lick Creek Quadrangle (fig. 6, column C; and fig. 9). The limestone member

has several thin interbeds of shale; it is as thick as 50 feet in the study area but is absent locally because of pre-Pennsylvanian erosion (for example, near the center of Sec. 25, T11S, R1E).

The limestone is light to medium gray and brownish gray, locally dark gray, and generally weathers light gray. It is dominantly a medium to coarse grained crinoidal packstone and grainstone but ranges from very fine to very coarse grained. The lower Goreville is skeletal packstone to wackestone that contains pellets and, locally, irregularly shaped tripolitic chert nodules, while the upper Goreville includes oolitic crinoidal packstone and grainstone. Foraminifera, brachiopods, bryozoans, molluscs, ostracods, and trilobites are common bioclasts, and oncoids are present. The lower part of the member is generally darker, finer grained, and more argillaceous than the upper part. The lower Goreville is abundantly fossiliferous, containing pelmatozoans, bryozoans (including unusually large specimens

of *Archimedes*), and rugose corals. Limestone beds 0.5 to 3 feet thick are separated by shale partings, which commonly are stylolitic.

The Goreville crops out in ledges 10 to 20 feet high, and karst topography is common in areas underlain by this unit. Contact with the overlying Grove Church Member is disconformable (Weibel and Norby 1992).

#### Grove Church Shale Member

This uppermost Mississippian unit was named by Swann (1963) for Cedar Grove Church in the Lick Creek Quadrangle. The type section is in a ravine just west of an unpaved road and in the ditch east of the road north of Cedar Grove Church in the NE NW, Section 31, T11S, R2E. Nelson et al. (1991) reduced the Grove Church to a member of the Kinkaid Limestone. The member is thin, exposed in only several places in the quadrangle, and crops out at three places in Section 31, T11S, R2E, Johnson County: (1) the type section, (2) just north of the road east of



Figure 7 The middle part of the Cave Hill Member in a limestone quarry, NE SE NE, Section 29, T11S, R1E. Staff is 5 feet long.

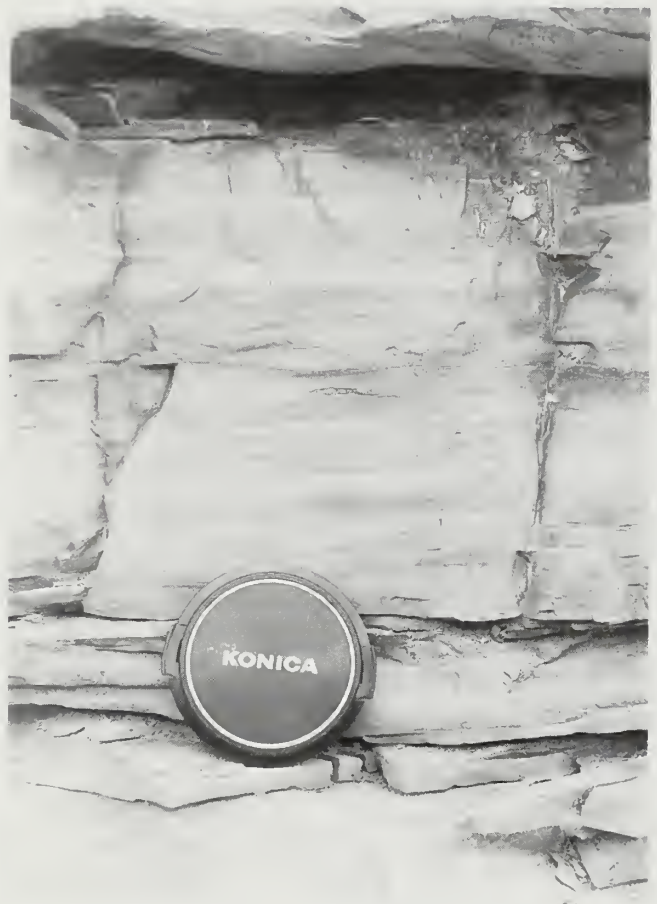


Figure 8 Laminated lime mudstone from the middle part of the Cave Hill Member in an abandoned quarry, SW SE, Section 10, T12S, R2E.

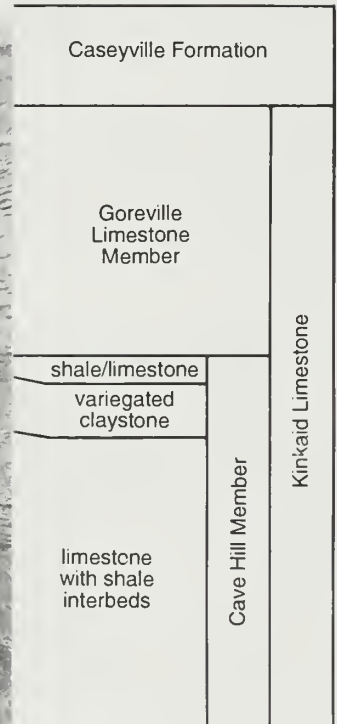
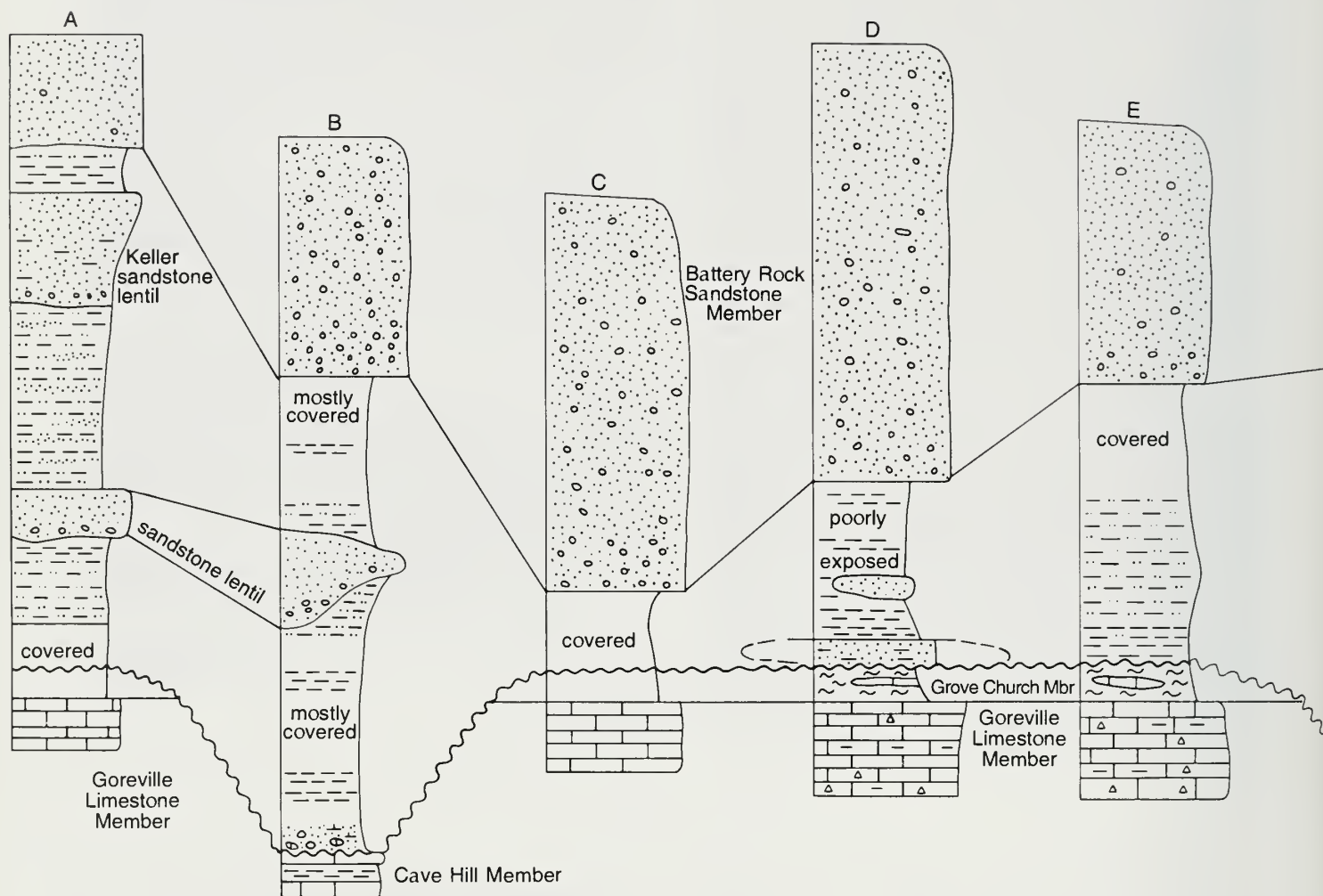


Figure 9 Quarry wall, viewed from the south, shows Kinkaid and Caseyville strata. The Goreville Limestone Member is about 40 feet thick. Location is SW SE, Section 10, T12S, R2E, Vienna Quadrangle.



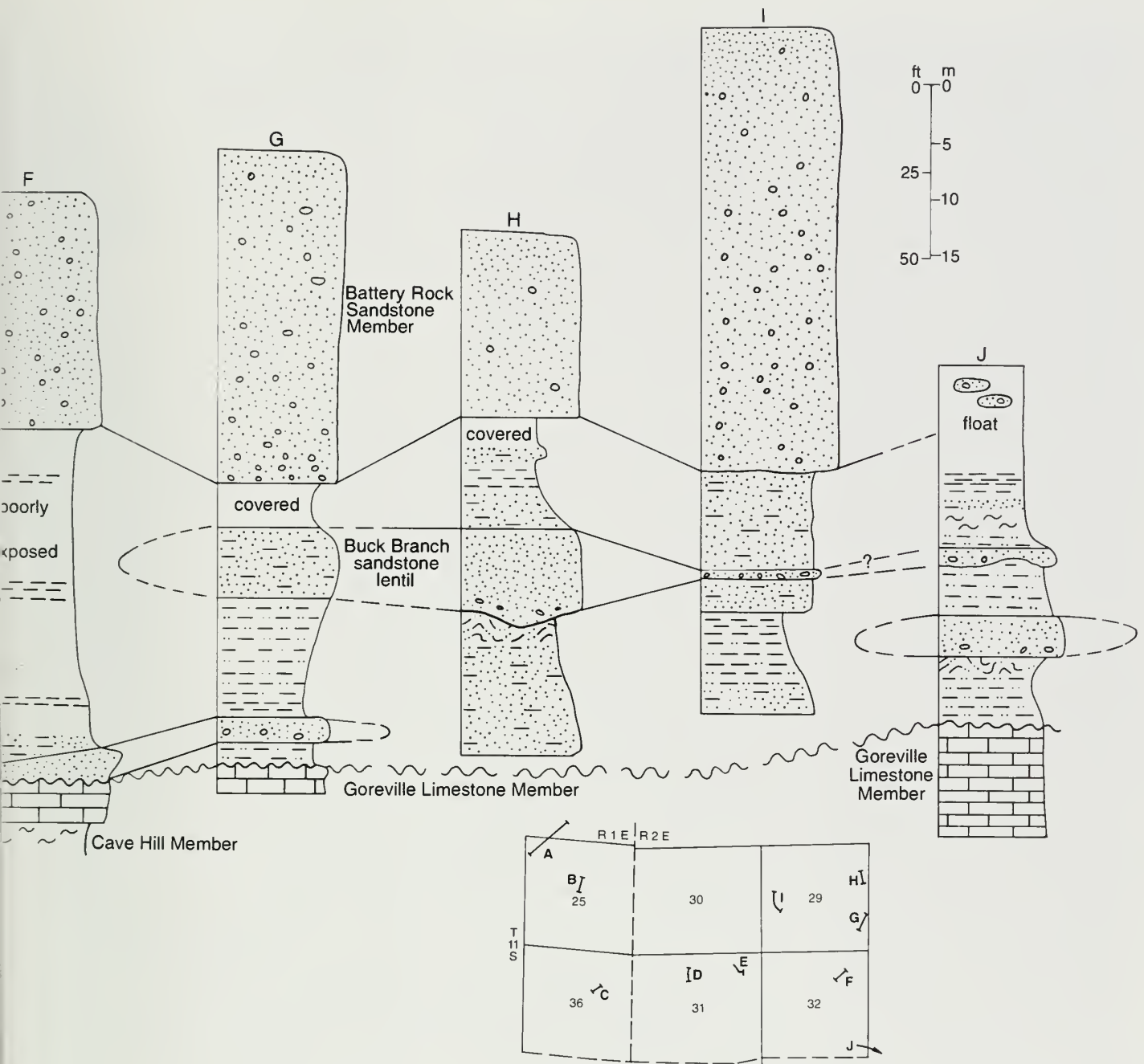
**Figure 10** Ten measured sections in the southeastern part of study area illustrate the Mississippian-Pennsylvanian unconformity and lithologic variation in the lower part of the Caseyville Formation. Datum is the base of the Goreville Limestone Member. Base map (inset) shows locations: (A) roadcut on I-57, (B) ravine west of Chimney Rock, (C) southwest face of Drapers Bluff, (D) Grove Church type locality in ravine and roadside, (E) ravine on the south side of Cedar Bluff, (F) ravine and hillside near Gurley Cemetery, (G) ravine and pond spillway near Ferne Clyffe State Park, (H) east fork of Buck Branch, (I) north-trending ravine and hillside, and (J) north-trending ravine in SW NE, Section 4, T12S, R2E, Goreville Quadrangle.

Cedar Grove Church, and (3) the ravine trending east-northeast just south of Cedar Bluff. The member also crops out in a southwest-trending ravine near the center of the SW NE NE, Section 27, T1E, R11S, Union County. At these exposures, the Grove Church consists of gray to olive gray and light brown, soft, non-calcareous to calcareous shale or claystone that contains limestone beds 0.3 to 1 foot thick. The limestone is gray, fine grained, argillaceous and fossiliferous skeletal packstone and wackestone.

The best record of the Grove Church is from the core from CO-

GEOMAP borehole L-2 (fig. 5). The basal 6 feet of the member consists of greenish gray, weakly calcareous mudstone that contains siderite nodules, common but poorly preserved casts of brachiopods and fenestrate bryozoans, and rare, flattened productid brachiopods. This shale grades upward to gray, noncalcareous mudstone about 11 feet thick, which in turn is overlain by 0.85 foot of dark gray, weakly calcareous silty shale that contains coal laminae and carbonaceous plant impressions. The uppermost unit of the Grove Church in the core is 4-foot-thick, interbedded, highly fossiliferous cal-

careous shale and limestone. Limestone occurs as nodules and poorly defined beds. Petrographically, the limestone ranges from skeletal wackestone to grainstone. Bioclasts are largely pelmatozoan fragments, but brachiopods, bryozoans, foraminifera, fish debris, ostracodes, rugose corals, and trilobites are present. Flora and fauna from the type locality were listed by Jennings and Fraunfelder (1986). Conodonts from the member have been documented by Rexroad and Merrill (1985), Manger and Sutherland (1987), and Weibel and Norby (1992).



The Grove Church is 22.2 feet thick in COGEOMAP borehole L-2 (fig. 5). Swann (1963) measured 16 feet at the type section. Less than 10 feet of strata is exposed at other outcrops in the study area.

### Mississippian-Pennsylvanian Boundary

Most geologists consider the Mississippian-Pennsylvanian boundary in the Illinois Basin to be a regional unconformity. Siever (1951), Wanless (1955), and Bristol and Howard (1971, 1974) described the boundary in southern Illinois, mapped the sub-Pennsylvanian surface, and mapped

a system of paleovalleys that are as deep as 400 feet and trend southwest across the sub-Pennsylvanian surface. The Mississippian-Pennsylvanian boundary is the Kaskaskia-Absaroka sequence boundary of Sloss (1963) and is attributed to a global eustatic event by Ross and Ross (1985) and Saunders and Ramsbottom (1986).

In the Lick Creek Quadrangle, the Mississippian-Pennsylvanian boundary is notably disconformable. Basal Pennsylvanian strata (Caseyville Formation) variably overlie the Grove Church, Goreville, or Cave Hill Members of the Kinkaid

Formation. Everywhere it has been observed, the actual contact is sharp and marked by an abrupt change in lithology.

A series of measured sections in the southeast quarter of the Lick Creek Quadrangle illustrates the unconformity (fig. 10). Near I-57 the Caseyville Formation overlies the Goreville Member of the Kinkaid (fig. 10, column A). Only 0.5 mile east of the highway, the Goreville is entirely missing, and basal Caseyville strata rest on the Cave Hill (fig. 10, column B). The basal bed of the Caseyville at this site is a conglomerate composed of limestone and chert

clasts as large as 0.2 foot, along with quartz granules and crinoid columnals in a matrix of calcareous sandstone. Farther southeast, the contact rises stratigraphically, so that the Goreville and Grove Church Members of the Kinkaid are preserved (fig. 10, columns D and E). Still farther east, the Caseyville again cuts down into the Goreville, as shown in sections from the ravine near Gurley Cemetery (fig. 10, column F) and the spillway of a farm pond near Ferne Clyffe State Park (fig. 10, column G).

Logs of wells east of the study area indicate that the Grove Church reaches a maximum thickness of about 70 feet. Where the Grove Church is thickest, the lower 40 to 50 feet is largely shale, and the upper part is largely limestone. Before erosion, the upper Grove Church limestone probably was a widespread, fairly uniform unit, like other limestone units within the Kinkaid. This upper Grove Church limestone represents erosional remnants of the youngest preserved Mississippian unit in the Illinois Basin.

Rexroad and Merrill (1985) challenged the hypothesis of a widespread sub-Pennsylvanian disconformity in the Illinois Basin. Reporting similar conodont faunas in the type Grove Church and in the overlying Wayside Member of the Caseyville Formation, these authors concluded that no significant hiatus exists between the two units. Rexroad and Merrill further argued that sedimentation may have been continuous across the Mississippian-Pennsylvanian boundary in the Grove Church type area. However, Jennings and Fraunfelder (1986) examined macrofossils from the Grove Church and Wayside type areas, found evidence for a "major hiatus" between the Grove Church and the Wayside, and further suggested that Wayside conodonts examined by Rexroad and Merrill (1985) were reworked from older strata. Weibel and Norby (1992) re-studied conodonts and lithostratigraphy of the Mississippian-Pennsylvanian boundary interval and concluded that a relatively short hiatus is present between the type Grove Church and Wayside Members.

## PENNSYLVANIAN SYSTEM

### Raccoon Creek Group

The name "Raccoon Creek Group" was first used by Wier and Gray (1961) for Pennsylvanian strata be-

low the Carbondale Formation in west-central Indiana. In southern Illinois, the Raccoon Creek Group comprises two formations: the Caseyville (older) and the Tradewater. The Raccoon Creek is composed almost entirely of siliciclastic rocks, in contrast to the underlying Pope Group, where limestone and siliciclastic intervals alternate.

The Caseyville and Tradewater Formations were differentiated in most of the Lick Creek Quadrangle. Near the west edge of the study area, however, these formations were not differentiated, and the Raccoon Creek Group is shown as a single unit on the geologic map.

**Caseyville Formation** The name "Caseyville" was first used by Owen (1856), but Lee (1916) was the first to describe the Formation in detail. The type section is on the west bluff of the Ohio River in eastern Hardin County, Illinois, opposite the village of Caseyville, Kentucky (Lee 1916). Approximately 500 feet of interbedded conglomeratic sandstone, shale, and thin coal and limestone layers constitute the type section.

Geologists differ about defining the Caseyville, but we distinguish the Caseyville from the overlying Tradewater Formation in southern Illinois by the character of the sandstones. Caseyville sandstones are quartz arenites that commonly contain quartz granules and small pebbles. In contrast, Tradewater sandstones are lithic arenites that rarely contain quartz granules but contain substantial amounts of feldspar, lithic fragments, mica, and clay matrix. Also, Caseyville sandstones are generally thicker, more massive, and better indurated than Tradewater sandstones (Nelson 1989). Shales, siltstones, and minor rock types of the Caseyville generally are not distinguishable from their counterparts in the Tradewater. The top of the Caseyville in the Lick Creek Quadrangle was mapped at the highest occurrence of quartz arenite that contains granules and pebbles. The Caseyville-Tradewater contact is mappable on the outcrops and in subsurface cores and well cuttings.

The Caseyville thins and becomes finer grained westward. East of I-57, outcropping Caseyville is 300 to 350 feet thick and contains bluff-forming, conglomeratic sandstones more than 100 feet thick. Wells in the northeast corner of the quadrangle indicate the Caseyville is 350 to 400 feet thick and contains as much as 90% sand-

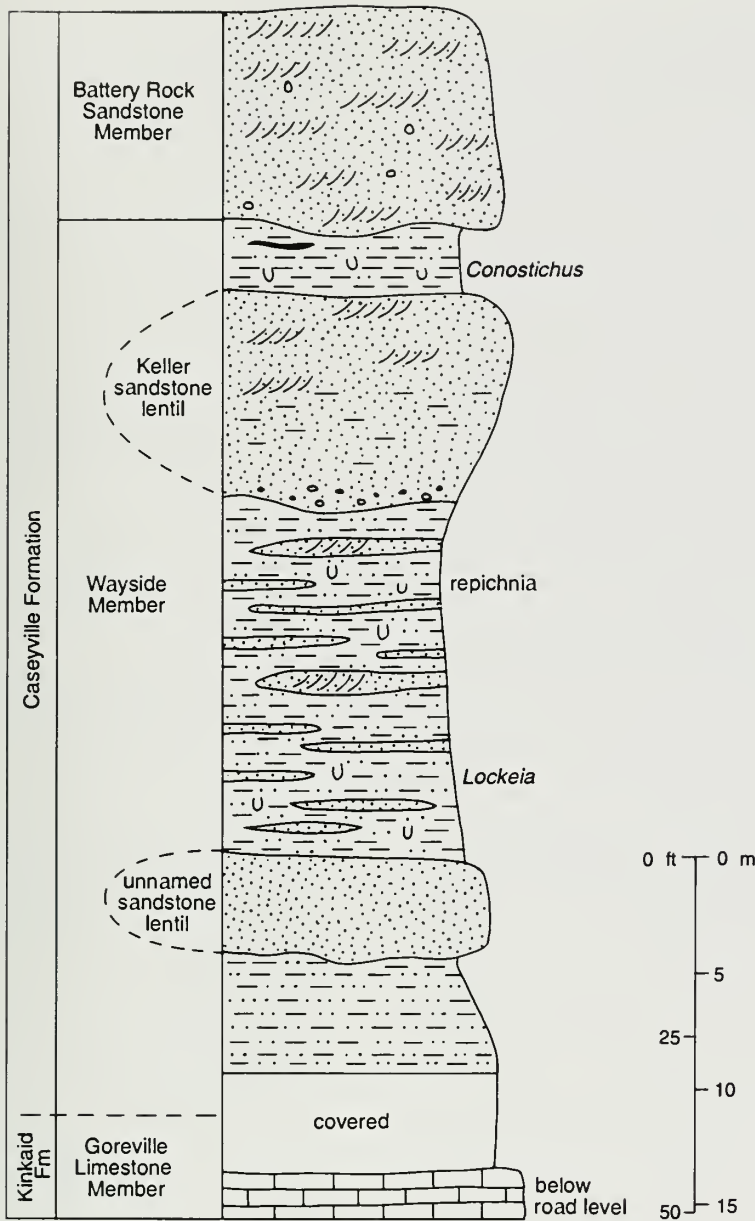
stone. West of I-57, the Caseyville thins to 180 feet in outcrops in the NW, Section 22, T11S, R2E, and to 220 feet in the Mitchell no. 1 Fly well in Section 9, T11S, R1E. West of I-57, sandstones in the Caseyville are less than 50 feet thick and lack quartz pebbles. These sandstones are discontinuously exposed near the west edge of the quadrangle, so that the Caseyville-Tradewater contact cannot be accurately located.

**Wayside Member** The Wayside Member was named by Lamar (1925) for the settlement of Wayside in the center of the Lick Creek Quadrangle. Lamar defined the Wayside as the interval of intercalated sandstone and shale underlying the Lick Creek (now Battery Rock) Sandstone at the base of the Pottsville (now Caseyville) Formation. Lamar did not designate a type section for the Wayside. Wanless (1956) stated that the Wayside type section occurs in ravines in the N½ of Section 30 and the NE NW, Section 31, T11S, R2E; but he did not publish a description of the section. The exposures cited by Wanless are poorly suited as a type or reference section because they contain numerous gaps and do not show contacts with adjacent units. A far superior exposure of the Wayside is the large roadcut along I-57 about 1.5 miles northeast of the Lick Creek interchange (NW NW, Sec. 25 and S½ SW, Sec. 24, T11S, R1E). We hereby designate this roadcut as the principal reference section of the Wayside Member (fig. 11; fig. 10, column A). The member is approximately 140 feet in this section, and all but the basal 15 feet is continuously exposed. The roadcut displays diverse sedimentary features of the Wayside and has been featured in published field guides (Ethridge et al. 1973, Palmer and Dutcher 1979).

The Wayside is composed largely of slope-forming, interbedded, and interlaminated (heterolithic) shale, siltstone, and fine grained, thinly bedded sandstone. Lenticular bodies of bluff-forming, crossbedded, and massive sandstone also occur in the member. In addition to the Buck Branch and Keller sandstone lentils (fig. 10), other, smaller sandstone lenses near the base of the Wayside have been mapped but not named.

The Wayside is readily mappable in the eastern two-thirds of the Lick Creek Quadrangle, where the overlying Battery Rock Sandstone Member is present. In the western third of the quadrangle, the Battery Rock





**Figure 11** Measured section in a roadcut along I-57 illustrates the reference section of the Wayside Member (SE SW, Section 24, and NW NW, Section 25, T11S, R1E).

is absent, and the Wayside cannot be distinguished from overlying strata of the upper part of the Caseyville Formation.

Among the heterolithic rocks that constitute the bulk of the Wayside, sandstone is the prevalent lithology. This sandstone is white to light gray, very fine to fine grained, well indurated quartz arenite. Grains are 95% or more monocrystalline, well sorted, and well rounded to subangular quartz. Polycrystalline quartz, muscovite, feldspar, lithic fragments (largely argillite), and stable heavy minerals such as zircon make up

the remainder of the rock. Some sandstones have calcite cement, whereas others have silica cement and sutured or pressure-welded grains. Siltstone in the Wayside is light to medium gray and quartzose, containing a higher proportion of mica and clay minerals than do the sandstones. Shale is medium to dark gray, rarely black, well laminated, and moderately to highly fissile. Most of the shale is silty, but thin intervals of clay shale and blocky claystone are present.

Conglomerate, a minor lithology in the lower part of the Wayside,

occurs as lenses less than 3 feet thick within heterolithic strata. Clasts of shale, siltstone, ironstone, and small quartz pebbles float in a matrix of sandstone that is cemented by calcite or iron oxide. Fragments of limestone, chert, and silicified fossils reworked from the Kinkaid Limestone were also observed in several places at the base of the Wayside.

Common sedimentary structures of thin bedded strata in the Wayside include interference ripples, current ripples, small load casts, tool marks, ball-and-pillow structures, and slumped bedding. All of these structures are present in the reference section along I-57 (fig. 11). Interference ripples and load casts are found at practically all outcrops of heterolithic Wayside. Most laminae and beds are a fraction of an inch to 3–4 inches thick, although occasional lenses of sandstone up to several feet thick are present. Thicker sandstone beds generally have sharp upper and lower contacts.

• **Fossils** A diverse marine fauna has been collected from thin bedded sandstone of the lower part of the Wayside Member. Rexroad and Merrill (1985) and Jennings and Fraunfelder (1986) together listed more than 40 species of marine invertebrates, including conodonts, coelenterates, brachiopods, pelecypods, gastropods, cephalopods, an arthropod, and crinoid columnals. Collections for both studies were made along the north-flowing tributary of Buck Branch in the W½ NE, Section 30, T11S, R2E. We also found fossils in the streambed in the SE SE NE, Section 30 and in the sandstone overlying the type Grove Church Shale in the NE NW, Section 31. Most fossils are poorly preserved molds and casts in sandstone and are not easy to find.

Trace fossils are common in heterolithic rocks of the Wayside throughout the study area. Most traces consist of simple, unbranched cylindrical burrows and poorly preserved trails not assignable to specific ichnogenera. Diverse trace fossils occur in the I-57 roadcut. In addition to unidentified trails and burrows, the trace fossils include numerous *repichnia*, *Lockeia*, and *Conostichus* (Joseph A. Devera, written communication 1993). The trace fossil *Conostichus* is interpreted as the resting place of a burrowing sea anemone and indicates a marine environment of deposition (Devera 1989).

Plant fossils, which are fairly common in siltstone and thin bedded sandstone of the Wayside, are mostly carbonized compressions or casts and molds of stem and bark fragments. Other plant fossils can be found with a diligent search. Among the 33 varieties of plant remains collected from the Wayside by Jennings and Fraunfelter (1986) are lycopods, sphenophytes, ferns, seed ferns, cordaites, seeds, and ovules. We found well preserved plant fossils along the large streambed in the SE NE NE, Section 29, T11S, R2E. They consist of compressions of leaves and stems and sand-filled stigmarian root casts, both found in gray shale that underlies a 2-foot-thick bed of black shale. Carbonaceous shale that contains abundant plant compressions also occurs just outside the study area along a north-flowing stream in the SW NE, Section 4, T12S, R2E, Goreville Quadrangle (fig. 10, column J).

• **Sandstone lentils** Mappable bodies of bluff-forming sandstone occur at or near the base of the Wayside in several areas. One such lentil is exposed in the I-57 roadcut and extends about 1 mile east of the highway (fig. 10, columns A and B). This lentil is about 30 feet above the base of the Caseyville Formation sandstone and is 14 feet thick in the roadcut, thickening locally to 25 feet. The sandstone is dominantly fine grained, but a basal conglomerate contains quartz, chert, and shale pebbles up to 2 inches in diameter. Trough and planar crossbedding are prominent, along with asymmetrical current ripples and contorted bedding (slumping or dewatering structures).

Other basal Wayside sandstone lenses occur in Sections 29 and 32, T11S, R2E (fig. 10, columns F and G). These sandstones are well sorted, very fine to fine grained quartz arenites that contain few or no quartz pebbles. Planar crossbedding and contorted bedding are common. The sandstones are up to 20 feet thick and 0 to 20 feet above the base of the Caseyville. The pinch-out of one of these sandstones can be seen along the road and hillside near the center of the E½, Section 31, T11S, R2E.

The **Buck Branch sandstone lentil** (informal name) forms cliffs and ledges along Buck Branch in Sections 19, 20, 29, and 30, T11S, R2E. The Buck Branch sandstone is up to 40 feet thick, and its base is 50 to 60

feet above the base of the Caseyville. The sandstone is dominantly fine to medium grained and well sorted, but sparse quartz granules and pebbles occur at the base. In places, the sandstone has well developed planar crossbedding that dips south or southeast, while in other places the rock appears massive or shows faint undulating and contorted laminations that suggest slumping or dewatering of the sand prior to lithification. The Buck Branch thins toward the south and grades into heterolithic strata (fig. 10, columns F and G). In the SW NW, Section 29, a thin conglomerate of ironstone clasts in a matrix of iron-rich sandstone occurs in the Buck Branch (fig. 10, column I). The Buck Branch is generally overlain conformably by heterolithic rocks, but near the center of Section 29, the Buck Branch is eroded at the base of the Battery Rock Sandstone. Lower contact of the Buck Branch is erosional and is well exposed at the northwest corner of Section 30 and in the E½ NE, Section 29 (fig. 10, column H). At these sites, the lower contact of the Buck Branch undulates strongly and truncates slumped bedding of underlying siltstones. A lag deposit of small quartz pebbles, shale and coal clasts, and fossil wood fragments is at the base of the Buck Branch in these outcrops.

The Buck Branch lentil may be equivalent to the Omar sandstone lentil of Jacobson (1991) in the Goreville Quadrangle.

The **Keller sandstone lentil** (informal name) crops out near Keller Cemetery in the western part of Section 28, T11S, R1E. The Keller thickens from a feather-edge east of I-57 to about 80 feet thick in the NE, Section 20, T11S, R1E. The base of the Keller lies 20 to 100 feet above the base of the Caseyville Formation. The Buck Branch and Keller sandstones are lithologically similar and occur at about the same stratigraphic position. Where the Keller is thick, it generally becomes coarser grained and contains quartz pebbles, particularly near the base. The lower contact, where observed, is erosional (fig. 10, column A, and fig. 11). A basal lag conglomerate of shale clasts was seen in several places. Near the west edge of the quadrangle the Keller crops out as two ledge-forming sandstones separated by a covered (presumably shaley) interval. The upper part of the Keller is fine grained, crossbedded, and burrowed sandstone that is overlain with

a sharp contact by carbonaceous shale and claystone.

**Battery Rock Sandstone Member** Cox (1875) named this member for a bluff called Battery Rock along the Ohio River in Hardin County, Illinois. The type section is part of the Caseyville type section. The Battery Rock crops out extensively in southern Illinois and parts of western Kentucky and is nearly continuous in the fluorspar district (Baxter et al. 1963, Baxter and Desborough 1965, Baxter et al. 1967) and westward in the Eddyville (Nelson and Lumm 1990a), Stonefort (Nelson and Lumm 1990b), Creal Springs (Trask and Jacobson 1990), and Goreville (Jacobson 1991) Quadrangles. The Battery Rock is the lower part of the Lick Creek Sandstone Member mapped by Lamar (1925) in the Carbondale 15-minute Quadrangle (fig. 12). Lamar's Lick Creek Sandstone also includes younger strata up to the top of the Pounds Sandstone Member of the Caseyville.

The Battery Rock is a coarse grained, pebbly to conglomeratic sandstone that forms cliffs as high as 140 feet in the southeast quarter of the quadrangle. Westward, the sandstone thins, loses its quartz pebbles, and becomes finer grained. It pinches out entirely in the SE, Section 15, T11S, R1E.

In the southeast, the Battery Rock is poorly sorted, coarse quartz arenite containing abundant, white, well rounded quartz pebbles up to about 1 inch in diameter. Pebbles occur as conglomeratic lenses and as laminae and stringers on foreset and bottomset beds of crossbedding; they are also scattered throughout the sandstone. Planar and trough crossbedding occur in bedsets 1 to 5 feet thick. Crossbedding is generally unidirectional, dipping south or southwest. Other sedimentary structures are scour or cut-and-fill features with pebble lags, and slumped or contorted laminations. The lower contact of the Battery Rock Sandstone in the southeastern area is erosional. The Buck Branch sandstone is entirely cut out near the center of Section 29, T11S, R2E, and partially cut out near the northwest corner of the same section. The upper contact of the Battery Rock Sandstone in this area is poorly exposed but probably conformable.

North and west of Buck Branch, the Battery Rock becomes dominantly fine grained, and quartz peb-

Lamar 1925		Kosanke et al. 1960		This report			
Pottsville Formation	Makanda sandstone member	Spoon Fm (part)		Tradewater Formation			
	Drury shale and sandstone member					Abbott Formation	
	Lick Creek sandstone Member	Caseyville Formation					Pound Sandstone Member
	Wayside sandstone and shale member					Drury Shale Member	unnamed
Battery Rock Sandstone Member			Battery Rock Sandstone Member				
	Wayside Sandstone Member	Wayside Member					

Figure 12 Pennsylvanian nomenclature used for the Lick Creek area.

bles are rare. Abrupt thickness and facies changes take place north of the branch in Sections 19 and 29, where the sandstone varies from 50 to 100 feet thick and intertongues with thin bedded, shaley sandstone and siltstone. Along I-57, the Battery Rock is about 30 feet thick and composed of fine grained crossbedded sandstone containing scattered quartz pebbles; the lower contact is erosional (figs. 10 and 11).

West of I-57, the Battery Rock is fine to medium grained, generally well sorted quartz arenite containing few or no quartz granules. It is medium to thick bedded and generally crossbedded. The lower contact is still erosional, whereas the upper contact is gradational to thin bedded sandstone and siltstone (fig. 13).

Near the northeast corner of the quadrangle (Sec. 29, T10S, R1E), logs and samples of three oil-test holes indicate the Battery Rock is nearly massive, fine to coarse grained sandstone 90 to 100 feet thick.

Southward, the Monjeb no. 1 Throgmorton well in Section 5, T11S, R2E, penetrated 295 feet of Caseyville Formation, of which all but the basal 45 feet is sandstone (fig. 14). The Caseyville sandstone is fine grained at the top, becoming coarse grained with quartz granules in the lower part. The Pounds, Battery Rock, and possibly Buck Branch

sandstones are "stacked" in the Throgmorton well. Wells in the western half of the study area indicate no thick sandstones in the Caseyville.

**Unnamed member** A slope-forming interval of heterolithic shale, siltstone, and thin bedded sandstone overlies the Battery Rock Member. The name "Drury Member" was formerly applied to this interval (Kosanke et al. 1960, Baxter et al. 1967, Nelson et al. 1991, Jacobson 1991); but the interval does not correspond to the Drury Sandstone and Shale Member as mapped by Lamar (1925). Mapping in the Lick Creek and Makanda Quadrangles (Jacobson and Weibel 1993) demonstrates that Lamar's Drury Member is largely in the lower part of the Tradewater Formation, although in some areas the Drury includes uppermost Caseyville strata (fig. 12). To avoid further confusion, we are abandoning the name "Drury Member" and leaving the member unnamed in this report. East of I-57, the unnamed member is 20 to 90 feet thick and forms a gently sloping or rolling bench or steeper slopes that are littered with talus from the overlying Pounds Sandstone. Exposures of the unnamed member are fragmentary. Small outcrops of medium to dark gray clay shale and silty shale, gray laminated siltstone, and very fine

grained laminated or thinly bedded sandstone occur in gullies and streambeds. No meaningful composite section can be assembled from these spotty exposures.

The uppermost 10 feet of the unnamed member is exposed at the southwest end of a large roadcut along I-57 in the NE SE NE, Section 24, T11S, R1E. Exposed strata consist of planar-laminated, gray silty shale and siltstone with lenticular interbeds of very fine grained quartz arenite (fig. 15). The contact to the overlying Pounds Sandstone is sharp and appears to be erosional. East of the highway in the SE, Section 19, T11S, R2E, a sandstone up to 20 feet thick that crops out above the unnamed member is fine grained quartz arenite with few pebbles. It is both overlain and underlain by poorly exposed, gray shale, siltstone, and thin bedded sandstone. The sandstone may be either an isolated lenticle or a westward-thinning tongue of the upper Battery Rock Sandstone.

Two well exposed sections of the unnamed interval are in deep ravines west of I-57 (fig. 13). In one exposure (fig. 13, column A), the interval is about 90 feet thick. Flaggy bedded, very fine quartz arenite at the base contains interference ripples and horizontal and vertical burrows. Above this base is gray silty shale, then intensively burrowed sandy siltstone. Just below the overlying Pounds Sandstone is sandstone containing stigmairian root casts, overlain by shale and siltstone containing plant stem and leaf fragments.

In the other exposure (fig. 13, column B) about 45 feet of fine grained strata is exposed. Shale at the base grades upward to thin bedded, burrowed sandstone, which in turn grades to siltstone and then to dark gray sideritic shale. Hence, this is a coarsening-upward cycle overlain by a fining-upward cycle. Contact to the Pounds Sandstone is concealed.

**Pounds Sandstone Member** The Pounds Sandstone Member was named by J.M. Weller (1940) for Pounds Hollow in Gallatin County, Illinois. The Pounds crops out extensively in southeastern Illinois and has been mapped westward from the type locality to the Lick Creek Quadrangle (Baxter et al. 1963, Baxter and Desborough 1965, Baxter et al. 1967, Nelson and Lumm 1990a and b, Trask and Jacobson 1990, Jacobson 1991). These authors char-

acterize the Pounds as a bluff-forming, massive or crossbedded, quartzose sandstone in which quartz pebbles are common but generally smaller and less abundant than in the Battery Rock Member. In most areas, the Pounds is the youngest sandstone having typical Caseyville lithology, and the top of the Caseyville is generally mapped at the top of the Pounds.

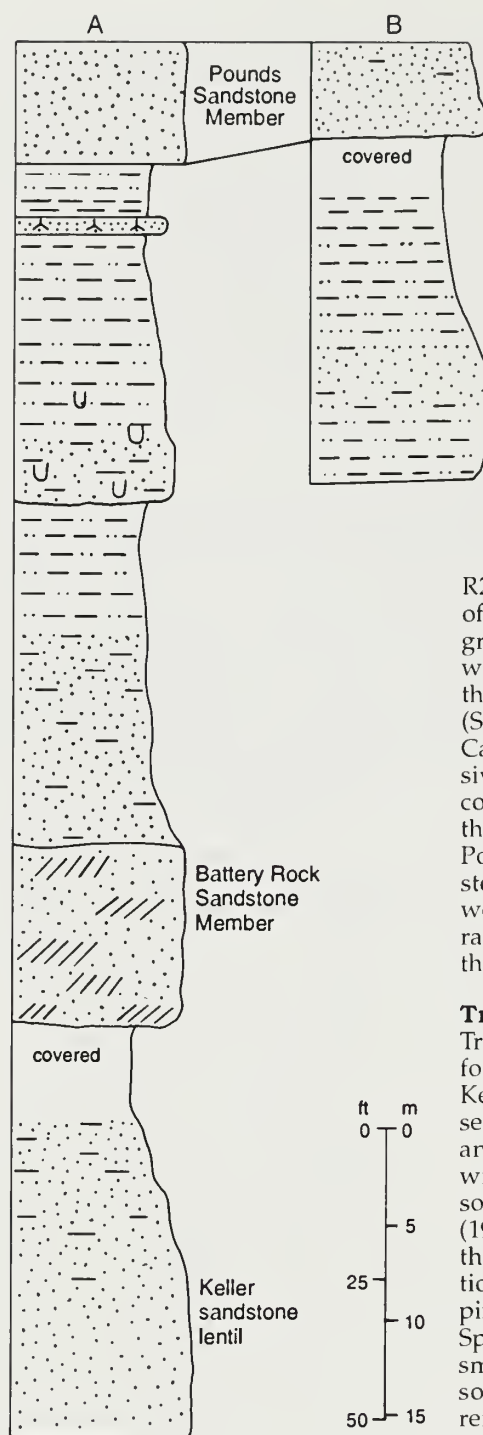
In the eastern half of the Lick Creek Quadrangle, the Pounds is 30 to 80 feet thick and forms rounded, south-facing cliffs. West of I-57, the Pounds becomes discontinuous and disappears near the west edge of the quadrangle.

The Pounds is composed dominantly of white to light gray, fine grained, well sorted quartz arenite. Quartz granules and small pebbles are less common in the quadrangle than they are farther east. Current ripples, interference ripples, and crossbedding are present, but much of the sandstone is nearly massive and displays faint, contorted, and slumped laminations. No trace fossils or body fossils have been observed.

The roadcut along I-57 (fig. 15) shows the sharp and apparently erosional lower contact of the Pounds, as well as the gradational upper contact, lateral intertonguing of sandstone, and overlying silty shale of the basal Tradewater Formation. The gradational upper contact is also visible in ravines east of the highway in Section 19 and the NW, Section 20, T11S, R2E. In these ravines, thick bedded, clean quartz sandstone of the Pounds grades upward through a 10- to 30-foot-thick interval to micaceous, brown weathering lithic arenites of the Tradewater Formation. The Caseyville-Tradewater contact was mapped at the highest occurrence of quartz arenite.

West of I-57, as the Pounds thins, its bedding generally becomes thinner, and shale and siltstone interbeds become more numerous. Interference and oscillatory ripple marks, small-scale crossbedding and cross-lamination, and burrows and other unidentified trace fossils are common. Crossbedding mostly dips southwest. As elsewhere in the quadrangle, lower contact is sharp, and upper contact is gradational. The sandstone generally is coarsest at the base and becomes finer grained and more thinly bedded upward (fig. 13).

The Pounds crops out along several north-flowing streams in the northern half of the Lick Creek Quad-



**Figure 13** Two measured sections of the Caseyville Formation west of I-57: (A) ravine in E½ SW and SE NW, Section 14, T11S, R1E, and (B) ravine in SW NW SE, Section 15, T11S, R1E.

In three wells in Section 29, T10S, R2E, the upper Caseyville consists of 165 to 220 feet of fine to coarse grained, partly pebbly sandstone with few or no shaley interbeds. In the Monjeb no. 1 Throgmorton well (Section 5, T11S, R2E), the upper Caseyville contains 250 feet of massive sandstone, grading from very coarse at the base to fine grained at the top (fig. 14). Evidently, the Pounds and Battery Rock Sandstones are superimposed in these wells. These four wells in the quadrangle have the only reliable logs of the upper Caseyville.

**Tradewater Formation** The Tradewater Formation was named for the Tradewater River in western Kentucky by Glenn (1912). The type section was described by Lee (1916), and the formation has been mapped widely in western Kentucky and southern Illinois. Kosanke et al. (1960) divided the Tradewater into the Abbott (older) and Spoon Formations in Illinois, but subsequent mapping shows that the Abbott and Spoon are distinguishable only in small areas (Nelson et al. 1991, Jacobson 1991). Accordingly, this report reintroduces the Tradewater Formation in southern Illinois.

The Tradewater is an interval of intercalated sandstone, siltstone, shale, and thin, lenticular coal and limestone. It can be distinguished from the Caseyville by the character of the sandstones. Caseyville sandstones are dominantly quartz arenites, whereas Tradewater sandstones are lithic arenites (subgraywackes) that contain conspicuous amounts of lithic fragments, feldspar, mica, and interstitial clay. Quartz granules and small pebbles occur in lower Tradewater sandstones but are uncommon.

range, including Grassy Creek and the large stream west of Grassy Creek (flowing to Devils Kitchen Lake). Here the sandstone is very fine to fine grained quartz arenite with rare granules. Tabular-planar and wedge-planar crossbedding occurs in sets as thick as 6 feet and dips southeast, east, and north (fig. 16). Current and interference ripples having diverse orientations also were noted, along with unidentified burrows and poorly preserved plant remains.

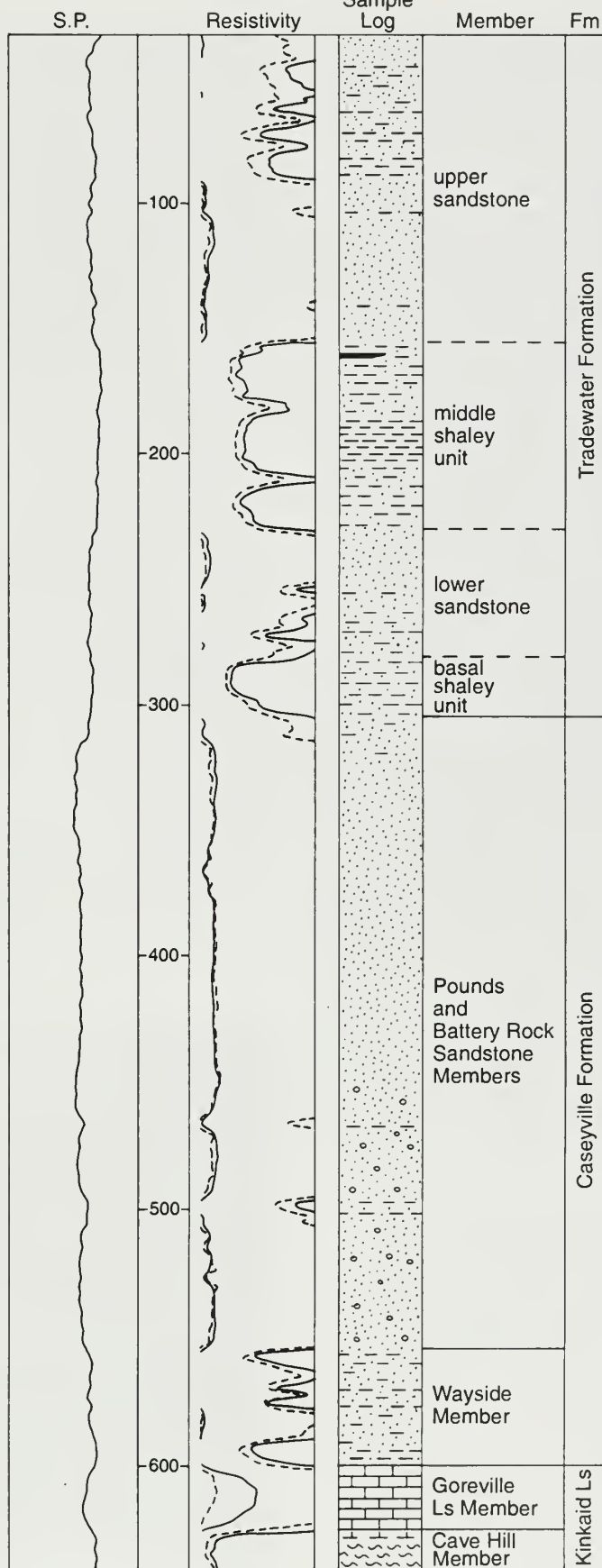
The upper part of the Tradewater has been eroded throughout the Lick Creek Quadrangle; its maximum thickness, in wells in Section 29, T10S, R2E, is about 300 feet.

Exposures of the Tradewater generally are poor. The formation mainly underlies a dip slope that is mantled with loess and, toward the north, with glacial drift. Most sandstones are weakly indurated and do not form long, continuous bluffs as do Caseyville sandstones. Outcrops of the fine grained strata are mostly fragmentary. The best Tradewater exposure is a roadcut along I-57 (NE, Sec. 24, T11S, R1E), which shows the basal 80 feet of the formation.

The lithologic succession of the Tradewater is known largely from well records, particularly from CO-GEOMAP borehole G-1, in which the Tradewater was continuously cored (fig. 17). The succession varies, but four informal members can be recognized in most of the quadrangle: (1) basal shaley member, (2) lower sandstone member, (3) middle shaley member, and (4) upper sandstone member. Boundaries of these units are too poorly exposed to map in most areas. On the geologic map, we show ledge-forming sandstones, designated as lower Tradewater (*lts*) and other Tradewater sandstones (*ts*).

**Basal shaley member** The basal 30 to 60 feet of the Tradewater Formation in the study area is mainly silty shale and siltstone, containing thin, lenticular coalbeds. This basal shaley member is equivalent to the Ferne Clyffe member (informal) of Jacobson (1991) in the adjacent Goreville Quadrangle.

The basal shaley member is fully exposed in the roadcut along I-57 in the SW NW NW, Section 19, T11S, R2E. Here, the member is 30 to 40 feet thick and consists of dark gray, fissile shale interlaminated with light gray siltstone to very fine grained sandstone (fig. 15). Sandstone interbeds become thinner and less numerous upward. Planar lamination, flaser bedding, current and interference ripples, and crosslamination (in siltstone) are prevalent. Small-scale growth faults (fig. 18), slumped bedding, and ball-and-pillow structures occur in the roadcut. Trace fossils are locally abundant and include forms having marine affinities. Fossils consist of *Lockeia*, the repichnia *Uchirites* and *Koupichnium*, *Cruziana*, and various cubichnia, repichnia, and domichnia, as well as resting-traces of an unidentified shrimplike organism



**Figure 14** Geophysical logs and sample log (graphic) column of Pennsylvanian strata in Monjeb Minerals no. 1 Throgmorton borehole, SW NE SW, Section 5, T11S, R2E, Johnson County, ISGS County no. 20370.

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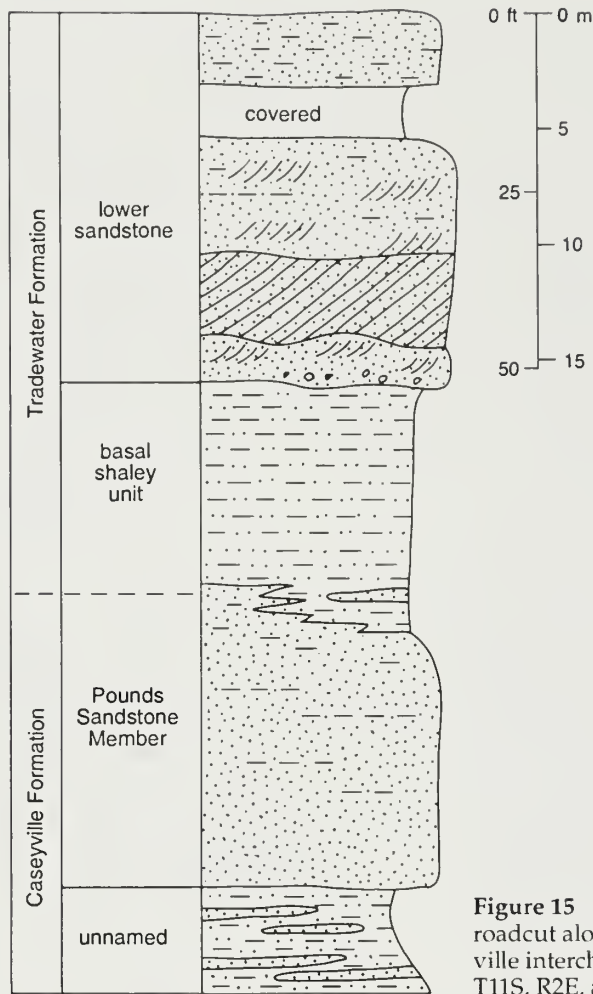
(Devera 1989). The basal shaley member intertongues with the underlying Pounds Sandstone and is overlain with erosional contact by sandstone.

Borehole data and outcrops in the northeast quarter of the Lick Creek Quadrangle indicate thin coal or highly carbonaceous shale in the basal Tradewater. In COGEMAP borehole G-1, a 1.1-foot-thick bed of bright-banded coal, which overlies claystone containing stigmarian rootlets, was cored (fig. 16). Coal occurs near the same position in samples from two oil-test holes close to COGEMAP borehole G-1. In the first sample, a 2-inch-thick coal bed overlies rooted claystone and is overlain by dark gray clay shale in a streambed in the SW SW NW, Section 1, T11S, R1E. This coal is very close to the base of the Tradewater. In the second sample, coal laminae occur in sandstone along the streambed north of Little Grassy Lake near the center of the NE NW, Section 4, T11S, R1E. These scattered occurrences probably represent more than one coal bed. Palynological study by Russel A. Peppers (written communications 1988) indicates basal Tradewater coals in the Lick Creek Quadrangle are equivalent to the Reynoldsburg Coal Bed or the slightly younger Bell Coal Bed. Both of these coals are present in quadrangles east of Lick Creek, although they are lenticular.

Sandstone occurs at the base of the Tradewater east of I-57 in the northern parts of Sections 19 and 20, T11S, R2E. This sandstone is a slightly micaceous, argillaceous, lithic arenite that grades downward to quartz arenite of the Caseyville Formation.

**Lower sandstone member** The lower sandstone member of the Tradewater Formation is 30 to 90 feet thick. This member crops out discontinuously near the crest of the south-facing drainage divide in the central Lick Creek Quadrangle and along several streams that flow north from that divide. We mapped the sandstone where it is well exposed and did not attempt to project it through covered areas (Weibel and Nelson 1993). Generally, the lower sandstone is friable and weathers deeply, forming outcrops only on steep hillsides.

This member is composed of brown-weathering, micaceous, lithic arenite that generally is poorly



**Figure 15** Measured section in a roadcut along I-57 south of the Goreville interchange (Secs. 18 and 19, T11S, R2E, and Sec. 24, T11S, R1E).



**Figure 16** Tabular-planar crossbedding in Pounds Sandstone, west side of Grassy Creek, SW NW, Section 7, T11S, R1E. Foreset beds dip east. Staff is 5 feet long.

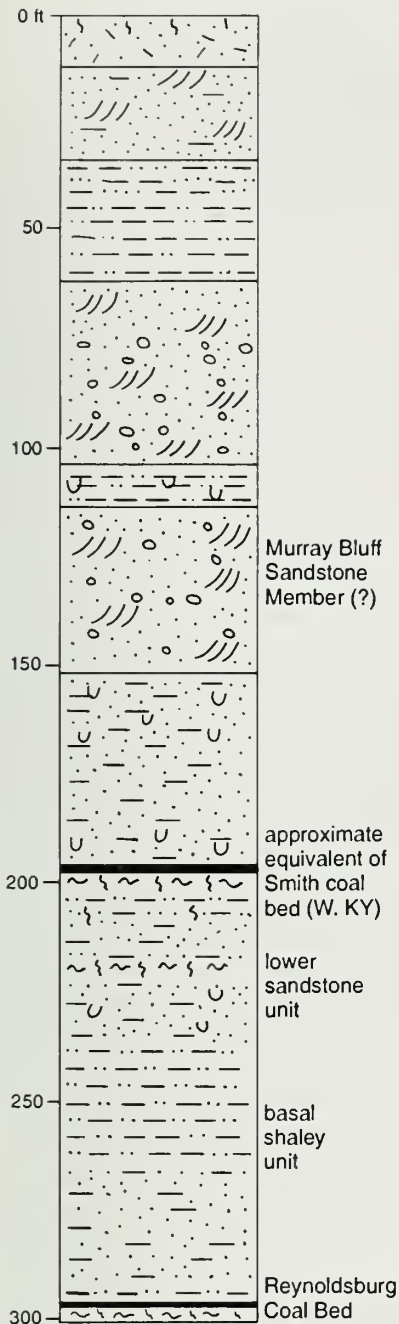


Figure 17 Graphic column of COGEO- MAP borehole G-1.

sorted and fine to coarse grained. Quartz granules and small pebbles locally occur at or near the base. Bedding varies but generally is thick, and crossbedding is well developed. Most of the observed foreset beds dip south or southeast, but several dip north.

The lower sandstone member is well exposed in the roadcut along I-57 just southwest of the Goreville interchange, where the member is 50 to 60 feet thick, with the upper contact covered (fig. 15). The member

can be divided into three separate sandstone bodies above one another, each separated by erosional contacts. A basal, lenticular unit of coarse, conglomeratic sandstone is 1 to 15 feet thick and displays large-scale trough crossbedding and small-scale ripple lamination. A lag conglomerate of shale, ironstone, and quartz pebbles overlies the erosional lower contact. The middle unit is 7 to 12 feet of fine to coarse grained sandstone that has huge, planar, southwest-dipping foreset beds (fig. 19). Current ripple marks superimposed on the foreset beds show northerly paleocurrent; hence, the middle sandstone represents bidirectional currents. Foreset laminae are arranged in thin-thick couplets that are consistent with neap-spring tidal cycles (Kvale and Uhler 1988, Kvale and Archer 1991). The upper unit is fine grained, lithic arenite with siltstone and shale interbeds, ripple marks, and small-scale trough crossbedding.

The lower sandstone member in the core of COGEO- MAP borehole G-1 (fig. 17) is a fine grained, shaley sandstone 60 to 100 feet above the base of the Tradewater. It is thoroughly burrowed, and part of it is a strongly calcareous interval and contains crinoid and brachiopod fragments. Stigmatic root casts occur above and below the calcareous marine zone. At the top, the sandstone grades to rooted claystone and a bright banded, pyritic coal bed 1.1 feet thick.

The lower sandstone member is equivalent to, if not continuous with, the Cedar Creek sandstone lentic, mapped by Jacobson (1991) in the Goreville Quadrangle and by Trask and Jacobson (1990) in the Creal Springs Quadrangle, east of the study area. Palynological study indicates that the coal that directly overlies the lower sandstone in COGEO- MAP borehole G-1 correlates with the Smith coal bed in western Kentucky (Russel A. Peppers, written communication 1989). The Smith coal occurs slightly below the middle of the Tradewater Formation in Kentucky, overlying the Finnie Sandstone Member and underlying the Lead Creek Limestone Member (Peppers 1988). Thus, the lower sandstone is approximately equivalent to the Finnie Sandstone and to the Grindstaff Sandstone in the fluorspar district.

**Middle shaley member** Overlying the lower sandstone member of the Tradewater is an interval of shale

that is 40 to 65 feet thick, as determined by subsurface data. This unit is poorly known in the Lick Creek Quadrangle because outcrops and borehole records are few.

The middle shaley member was cored continuously in COGEO- MAP borehole G-1, where the member is about 40 feet thick and consists of siltstone to fine grained sandstone that contains laminae of gray shale (fig. 17). Vertical and horizontal burrows occur throughout the unit; portions of the core are so intensively burrowed that lamination is obliterated. The core also contains several zones of intraformational conglomerate that contain clasts of coal, shale, and siderite. The burrowed unit directly overlies coal (palynologically equivalent to the Smith coal bed) and is sharply overlain by crossbedded upper Tradewater sandstone.

The middle shaley member is about 65 feet thick in the Monjeb no. 1 Throgmorton well (Sec. 5, T11S, R2E) and composed of medium to dark gray silty, carbonaceous shale and siltstone, grading at the base to very fine grained sandstone. Near the top of the interval is black, highly carbonaceous shale that contains pyrite crystals and coarse plant remains.

On the outcrop, the middle shaley member is interlaminated with siltstone, with occasional lenses and interbeds of sandstone. The shale is medium to dark gray, fissile, and noncalcareous, and contains siderite nodules. Siltstone is light gray to brown and quartzose; sandstone is very fine grained, silty, and laminated to thinly bedded. Shale rip-up clasts, fragmentary plant remains, burrows, and other unidentified trace fossils are common in the member.

The middle shaley member lithologically resembles and occupies the same stratigraphic position as the Lake of Egypt member in the Goreville Quadrangle (Jacobson 1992) and the olive shale member in the Creal Springs, Stonefort, and Eddyville Quadrangles (Nelson et al. 1991). Palynology of associated coals suggests the middle shaley member may be equivalent to the Lead Creek Limestone Member in western Kentucky (Peppers 1988).

**Upper sandstone member** The youngest part of the Tradewater Formation in the quadrangle consists of sandstone with local interbeds of siltstone and shale. Thickness of this

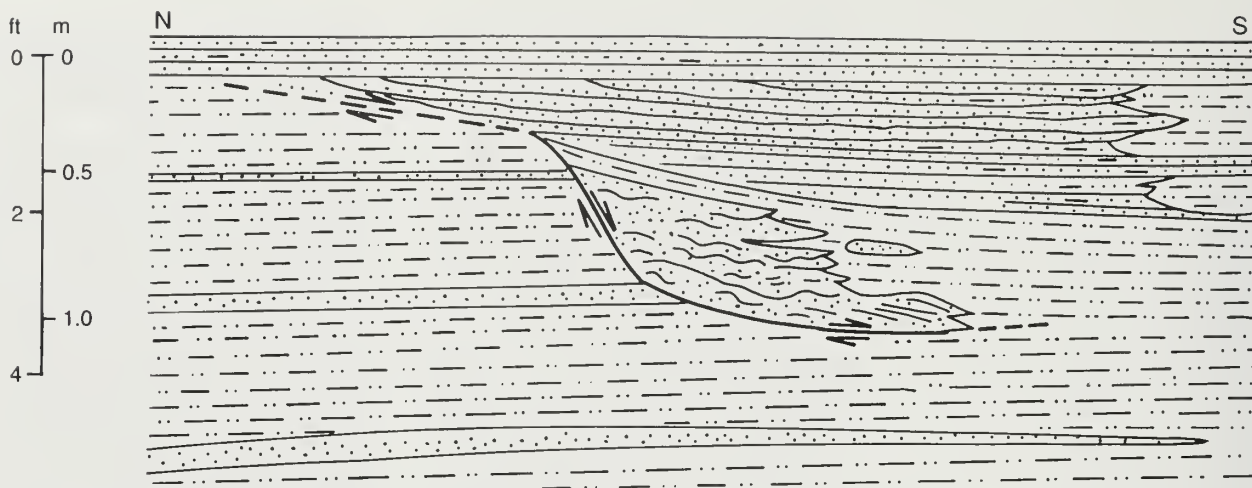


Figure 18 Sketch of a small growth fault in the interlaminated shale and sandstone of the basal Tradewater Formation in a roadcut along I-57. Location is given in figure 15.



Figure 19 Huge tabular-planar crossbedding in sandstone of the lower Tradewater Formation in a roadcut along I-57. Foreset beds dip southwest. The alternating thin and thick foreset laminations, most clearly visible at the left side of the photo, have been interpreted as reflecting tidal ebb and flow cycles (Kvale and Archer 1991).

upper sandstone member has not been determined adequately but may be as much as 150 feet. Sandstones shown with the symbol *ts* on the geologic map (Weibel and Nelson 1993) belong to this member.

The upper sandstone member crops out discontinuously along north-flowing drainages in the northern half of the quadrangle. The rock is locally well indurated, but in most places, it is weakly cemented and erodes easily. Locally, the upper sandstone forms cliffs as high as 60 feet.

The upper sandstone generally is very fine to fine grained and com-

posed of subrounded to subangular quartz sand along with considerable amounts of lithic fragments, mica, feldspar, and clay matrix. Fresh rock is light gray or yellowish gray, whereas weathered surfaces are generally brown and encrusted with iron oxides. Bedding varies from thin to massive, but most of the outcropping sandstone has irregular, thick bedding. Tabular-planar crossbedding occurs in sets as thick as 5 feet; foreset beds generally dip southward. Crossbed orientations are diverse near the spillway of a pond in the NE NE, Section 26, T10S, R1E. Shallow troughs bearing

current ripples indicating westerly paleocurrents were observed along Little Wolf Creek near the north edge of the quadrangle. Nearly massive sandstone bearing faint, slumped, and contorted laminae is exposed along Wolf and Middle Wolf Creeks at the north edge of the quadrangle.

Although the upper sandstone is predominantly lithic arenite, clean quartzose sandstone that approaches quartz arenite occurs in several places. Clean sandstone on the northeast side of Devils Kitchen Lake in the SW SW, Section 26, T10S, R1E, appears to grade westward to lithic arenite. Clean quartz sandstone is interbedded with lithic arenite just north of the study area on the west shore of Herrin Lake, NW SW, Section 20, T10S, R2E, Crab Orchard Lake Quadrangle. These sandstones, 200 to 300 feet above the base of the Tradewater, resemble those of the Caseyville Formation except for the absence of quartz granules.

The upper sandstone of the Tradewater in the core of COGEOMAP borehole G-1 (fig. 17) consists of 150 feet of sandstone with interbeds of medium to dark gray silty shale. The sandstone is fine to coarse grained and crossbedded, and contains rip-up clasts of shale, siderite, and coal. This sandstone is coarser grained than that observed on nearby outcrops.

The upper sandstone is at least partly continuous with the Murray Bluff Sandstone Member, mapped in quadrangles to the east. The upper sandstone in the Lick Creek Quadrangle, however, probably also includes strata younger than the Murray Bluff.



## QUATERNARY SYSTEM

Bedrock geology was the principal focus of this study, and most Quaternary deposits were not mapped or examined in detail. The Glasford Formation was mapped because it shows interesting relationships to geomorphology at the southern margin of Pleistocene continental glaciation.

### Pre-Illinoian Loess

Lamar (1925) described "pre-Illinoian loess" in an exposure along the road "a few hundred feet south of the center of the north line" in Section 36, T10S, R1E. A roadcut on the east side of the road at this location reveals yellow brown to orange brown loess that contains sub-angular sandstone clasts. This deposit probably is the Loveland Silt, a windblown deposit of Illinoian age that occurs in unglaciated areas of Illinois (Willman and Frye 1970, Frye and Willman 1975). The Loveland is probably widespread in the area, but it is generally covered by younger deposits, so drilling would be needed to determine its extent. As shown on the stratigraphic column of the geologic map (Weibel and Nelson 1993), the Petersburg Silt may underlie the Glasford Formation in the northern part of the quadrangle. The Petersburg and Loveland are equivalent units; the name "Petersburg" is used where the Glasford overlies the silt (Willman and Frye 1970).

### Glasford Formation

Unlithified diamicton containing lenses of sand and gravel in the northern part of the Lick Creek Quadrangle is mapped as the Glasford Formation (Weibel and Nelson 1993). The Glasford was named for a town in Peoria County, Illinois, and is interpreted as glacial till with intercalated outwash deposits and overlying accretion-gley deposits (Willman and Frye 1970). Lamar (1925) used the term "Illinoian glacial drift" for the deposits assigned in this report to the Glasford Formation.

The Glasford occurs mostly along valleys in the northeastern corner of the quadrangle (fig. 20). It probably also occurs to the northwest, but is largely submerged beneath Devils Kitchen and Little Grassy Lakes. Near the north edge of the quadrangle, the Glasford partly extends across upland divides, where it is difficult to map because it is mantled

by thick loess. Good exposures of the Glasford were observed in cutbanks of Wolf Creek in the NE, Section 32, T10S, R2E; in cutbanks and landslide scarps on the north side of Grassy Creek in the S½, Section 25, T10S, R2E; in the spillway of a lake in the SW NE, Section 29, T10S, R2E; and in an east-trending ravine near the northwest corner of the NE SW, Section 27, T10S, R1E. Because the Glasford is not lithified, most exposures are short lived.

Glasford sediments in the study area are mostly diamicton that is composed of silty clay with minor amounts of sand and gravel and occasional cobbles and boulders (figs. 21 and 22). The silty clay is light gray to medium brownish or bluish gray and weathers yellowish gray. Sand and pebbles are scattered throughout the diamicton and also occur as small, discrete lenses and stringers. Sand grains are light gray to orange brown and composed mainly of rounded to subrounded quartz and chert. Angular or only slightly abraded sandstone clasts derived from the Tradewater Formation or younger Pennsylvanian strata are common and range in size from granules to slabs about 1 foot in maximum dimension. Erratics of granite and phaneritic, mafic igneous rock, basalt, and yellowish gray dolomite are common in places. They are mostly well rounded and range from small pebbles to boulders 4 feet in diameter. Erratics are largest and most numerous near Devils Kitchen Lake, whereas only occasional small, igneous pebbles occur along Wolf and Middle Wolf Creeks.

Glasford deposits generally lack sorting, grading, or stratification (figs. 21 and 22). The only stratified sediments are thin, discontinuous layers of sand and sandstone clasts. Sand lenses vary from horizontal to steeply tilted; some are contorted, which suggests slumping and deformation while in a viscous state.

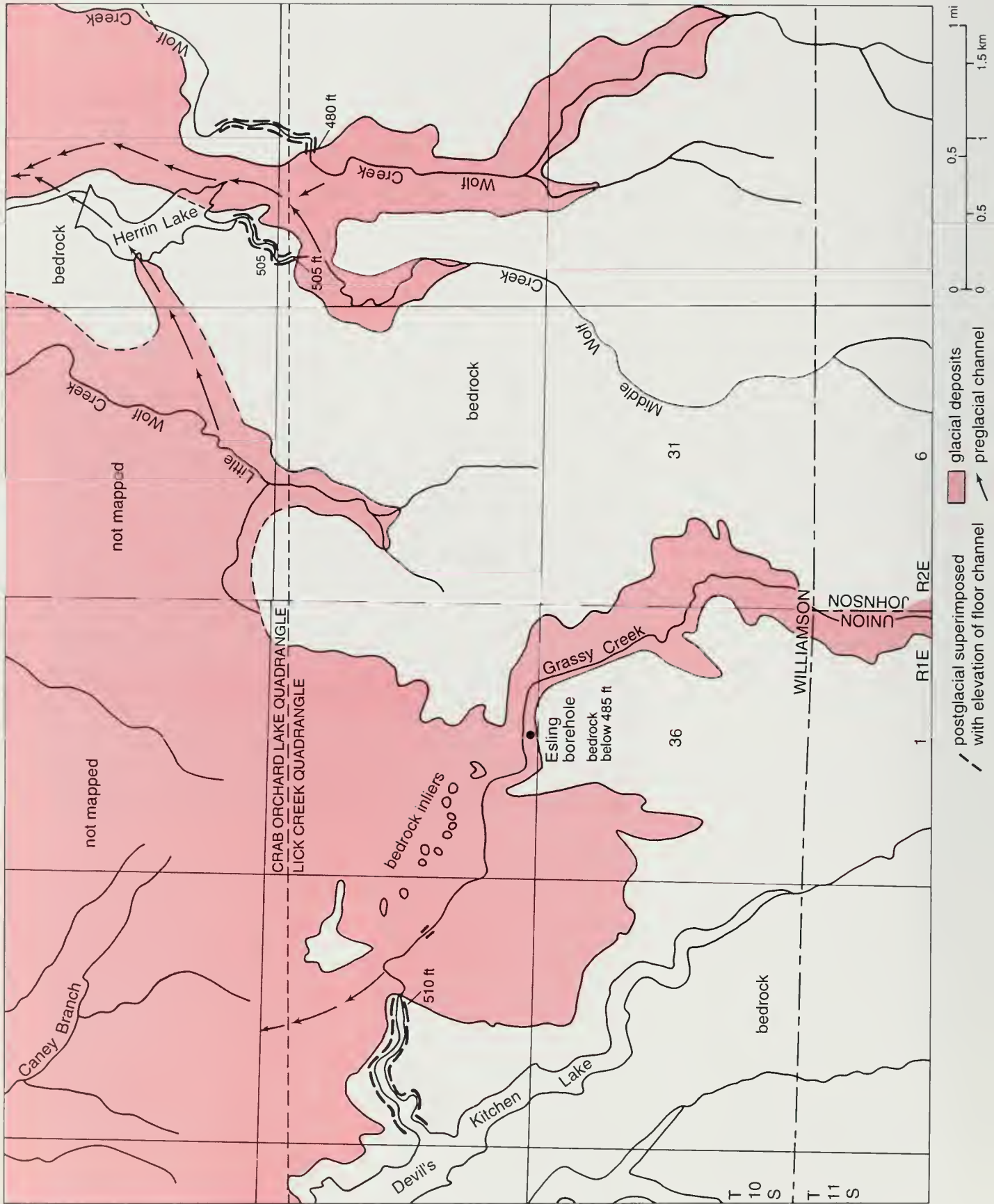
Along Grassy Creek in the S½ SW SE, Section 25, T10S, R1E, Glasford diamicton contains prominent polygonal joints that are lined with iron oxides (fig. 22). Leon Follmer (written communication 1989) interpreted the joints as dessication cracks filled with secondary weathering products and representing a mature weathering profile in the "C" horizon of the Sangamon Soil. Embedded in the diamicton at the same site are fragments of partially

oxidized wood, which are radio-carbon-dated as older than 40,000 years, a finding consistent with Illinoian age (Follmer, written communication).

Thickness of the Glasford Formation in the study area is difficult to assess because the sediment was deposited on an uneven bedrock surface and few well records are available. A test hole on the floodplain of Grassy Creek in the SW SW SE, Section 25, T10S, R1E, penetrated 55 feet of Glasford sediments without reaching bedrock (Steven Esling, personal communication 1988). Immediately north of the drill site, the Glasford extends 60 feet up the hillside, implying a minimum thickness of 115 feet. The Glasford may be thicker than 120 feet along the divide between Wolf and Middle Wolf Creeks at the north edge of the quadrangle. In the valleys of all the large streams in the northeast quarter of the quadrangle, the Glasford probably underlies Holocene alluvium. Judging by borehole data and the profiles of streams in unglaciated areas, the preglacial profiles of these creeks probably were V-shaped.

Along several north-trending valleys, Glasford sediments form terraces, which may occur along one or both sides of a valley and have steep slopes and nearly level tops. Elevations of terraces are consistent within a valley, but may differ among valleys. Terraces are at about 570 feet elevation along Wolf Creek, 550 feet along Middle Wolf Creek, 560 feet along Little Wolf Creek, and 620 feet along Grassy Creek. Many landslides are evident in terrace deposits along the steep valley walls, particularly on the north side of Grassy Creek.

Superimposed drainage developed along several creeks near the north edge of the quadrangle. Superimposed stream segments occupy narrow, sinuous to meandering gorges cut into Pennsylvanian sandstone. Wolf Creek and Middle Wolf Creek enter sandstone gorges at or just north of the north boundary of the quadrangle (fig. 20). The sandstone floor of Wolf Creek is at an elevation of 480 feet, and the floor of Middle Wolf Creek is at 505 feet. Midway between Wolf and Middle Wolf Creeks, the Glasford is exposed along a north-trending ravine down to an elevation of 475 feet—lower than bedrock exposures in Wolf and Middle Wolf Creeks. Hence, the creeks must have joined south of



their present intersection prior to deposition of the Glasford (fig. 20). After Glasford deposition, Wolf and Middle Wolf Creeks cut new channels through the Glasford into bedrock. Neither creek has cut its new channel as deeply as the preglacial channels that are now filled with Glasford sediments.

The superimposed segment of Grassy Creek (partially flooded by Devils Kitchen Lake) begins at the bridge near the center of Section 26, T10S, R1E. Here the stream flows on sandstone at an elevation of 505 feet (fig. 20). One mile upstream, a test hole was drilled in Glasford diamiction down to an elevation of 485 feet without reaching bedrock (Steven Esling, personal communication 1988). Hence, the pre-Glasford streambed of Grassy Creek at the well site was at least 20 feet lower in elevation than the present bedrock-floored streambed at the head of the narrows. The pre-Glasford course of Grassy Creek probably ran north or northwest of the bridge, where no bedrock crops out (fig. 20).

### Younger Loess

Windblown silt or loess overlies the Glasford Formation as well as Paleozoic bedrock throughout the Lick Creek Quadrangle, but these were not mapped or studied in detail. Clean exposures of loess are not common because of vegetation and slumping. Loess is commonly 3 to 5 feet thick in the study area, and locally is thicker than 10 feet.

Three stratigraphically distinct loesses are reported in southern Illinois (Willman and Frye 1980). The oldest of these, the Loveland Silt, was described above. The Roxana Silt and the overlying Peoria Silt are Wisconsinan and widespread in southern Illinois. Most loess at or near the surface in the Lick Creek Quadrangle is yellowish brown, light brown, or brownish gray, and probably is Peoria Silt rather than Roxana Silt, which tends to be pinkish gray. One of the few clean exposures of loess in the quadrangle is in the spillway of a lake in the SW NE, Section 29, T10S, R2E. At this site, brownish gray to yellowish brown

**Figure 20** Map showing distribution of Glasford Formation, preglacial bedrock channels, and postglacial superimposed drainages, in the northern Lick Creek and southern Crab Orchard Lake Quadrangles (facing page).

unstratified clayey silt or silt overlies diamiction of the Glasford Formation.

### Alluvium, Colluvium, and Talus

Alluvium (stream sediment) was mapped where it forms distinct floodplains in valleys. Alluvium overlies the Glasford Formation in valleys in the northern part of the quadrangle. Cutbank exposures and borehole records indicate that alluvium generally is only several feet thick. A thin layer of colluvium (a

mixture of loess and rock fragments) mantles most hillslopes in the quadrangle. Because bedrock geology was the primary emphasis of this survey, colluvium was not mapped. Talus (broken rock debris on steep slopes) was mapped only where it produces significant landforms and conceals bedrock. Mapped talus is mostly at the base of sandstone cliffs in the Caseyville Formation, where sandstone boulders up to the size of a house are randomly intermixed with smaller fragments.



**Figure 21** Exposure of diamiction of the Glasford Formation on the north side of Grassy Creek in SW SW SE, Section 25, T10S, R1E. Staff is 5 feet long.



**Figure 22** Diamiction of the Glasford Formation in a bed of Grassy Creek shows polygonal veins interpreted as desiccation cracks formed in a deep weathering profile of the Sangamon Soil (Leon Follmer, personal communication 1988).



## DEPOSITIONAL HISTORY

### MISSISSIPPIAN

Body fossils, trace fossils, sedimentary structures, and sedimentary sequences indicate that Pope Group (Chesterian) strata in the study area are of shallow marine and marginal marine origin. Lateral continuity and uniformity of thin units, particularly in the Menard, Clore, and Kinkaid Formations, point to tectonic stability in the study area.

The *Menard Formation* contains an abundant fauna that indicates deposition in marine water of normal salinity and oxygen content. The prevalence of lime mudstone and wackestone implies gentle waves and currents. Sources of terrigenous clastics were distant from the study area. The Menard may have been deposited in relatively deep water or in a shallow but protected setting, such as a broad bay.

The *Palestine Formation* is a siliciclastic unit that represents prograding deltas or shoreline. Ripple marks, crossbedding, and abundant burrows indicate moderate agitation in shallow water. Common plant remains and thin coal overlying a rooted zone are evidence of proximity to the shore and local subaerial exposure.

Like the Menard, the *Cora Member* of the Clore Formation contains abundant marine fossils throughout. The fauna and the micritic nature of the limestones indicate water of normal salinity and low to moderate turbulence and turbidity, probably on an open marine shelf (Abegg 1986).

The *Tygett Member* of the Clore contains two siliciclastic intervals that coarsen upward and are capped by rooted zones. The trace fossil *Rhizocorallium*, found just below the rooted zone of the lower sandstone, has strong marine affinities (Devera 1989). We concur with Abegg (1986) that most of the Tygett Member except the rooted zones represents subtidal sedimentation. The Tygett records two episodes of progradation, separated by a return to open marine conditions similar to those of Cora sedimentation.

Reduced clastic input allowed deposition of carbonate rocks in the overlying *Ford Station Member*. Dolomite, laminated lime mudstone and "bird's-eye" structures in the basal Ford Station limestone were interpreted by Abegg (1986) as tidal flat sediments (shallow subtidal to intertidal and possibly supratidal).

The *Degonia Formation* is lithologically similar to the Palestine and probably represents similar depositional conditions. Carbonaceous shales and rooted zones are evidence of subaerial exposure and terrestrial swamps. The regionally widespread red and green variegated claystone at the top of the Degonia is similar to other Chesterian strata interpreted as upper tidal flat to marsh deposits (Weimer et al. 1982). The thick sandstone of the Degonia near the west edge of the quadrangle is part of a system of southwest-trending sand bodies that exhibit paleocurrents toward the southwest (Potter 1963). West of the study area in the Cobden Quadrangle, bidirectional (herringbone) crossbedding and coupled crossbedding occur in sandstone of the Degonia and indicate tidal influence (Devera and Nelson 1995). Thick Degonia sand bodies may have been deposited in estuaries or as shallow, offshore, tidally constructed sand ridges (Off 1963).

The *Negli Creek Member* of the Kinkaid Formation grades upward from lime mudstone and wackestone in the lower part to packstone and grainstone in the upper part. Similar trends were observed in the Negli Creek east of the study area (Nelson et al. 1991). The trend implies upward shoaling and increase in depositional energy. Buchanan (1985) attributed micritic limestones of the lower Negli Creek to a protected marine shelf and upper Negli Creek packstone and grainstone to a more open shelf.

The *Cave Hill Member* contains three depositionally distinct submembers. The lower siliciclastic interval coarsens upward and becomes coarser and thicker northeast of the

study area. Thus, this interval represents clastics that prograded from the northeast (Randall 1970, Nelson et al. 1991). The middle Cave Hill contains a variety of carbonate rocks, which represent a variety of environments. Much of the middle Cave Hill consists of lime mudstone, some of it finely laminated, indicating very low depositional energy. Hardgrounds occur in the Southern Illinois Stone Company's quarry just outside the quadrangle (Joseph A. Devera, personal communication 1988). The variegated claystone near the top of the Cave Hill contains features typical of paleosols formed in arid or semiarid conditions, including blocky texture and carbonate glaebules. An alternative depositional setting is upper tidal flat to marsh (Weimer et al. 1982).

The *Goreville Limestone Member*, largely crinoidal grainstone, is a high-energy, shallow marine deposit. A regression at the end of Goreville sedimentation is marked by a paleosol (Weibel and Norby 1992).

The *Grove Church Shale Member* at its type locality records an initial transgression and deposition of prodeltaic mudstone, followed by regression and soil formation. Another transgression and deposition then occurred in a low-energy, near-shore marine environment (Weibel and Norby 1992). Judging by strata preserved in nearby areas (Nelson et al. 1991), at least another 50 feet of sediment, including a thick limestone was deposited before the major regression that marks the end of the Mississippian Period.

### PENNSYLVANIAN

#### Caseyville Formation

In three important aspects, Caseyville strata contrast with Pope Group strata: (1) near-total absence of carbonate rocks, (2) a marked increase in grain size, and (3) pronounced lenticularity of rock bodies. Pebbly quartz arenites lithologically and temporally equivalent to the Caseyville occur throughout large

regions of the eastern United States. Sedimentologic patterns point to sources in an active orogenic belt in the northeastern United States and southeastern Canada (Nelson 1989). Uplift in the source area, perhaps coupled with climatic changes, sent a greatly increased sediment load throughout the Illinois Basin. This influx of coarse clastics choked off carbonate sedimentation. Lenticular rock bodies and rapid facies changes reflect the irregular sub-Pennsylvanian surface along with concurrent tectonism, uneven compaction, loading, and shifting sediment transport routes. Despite these effects, eustatic changes are still evident in the rock record.

Previous geologists interpreted the Caseyville in and near the Lick Creek Quadrangle as largely deltaic sediments. Ethridge et al. (1973) suggested that two progradational deltaic sequences are represented in the lower Caseyville exposed along I-57. They interpreted upper Caseyville and lower Tradewater strata along I-57 as deposits of distributary channels, interdistributary bays, and related environments. In the same roadcuts, Koeninger and Mansfield (1979) identified a variety of deltaic environments, including channels, point bars, bays, floodplains, and marshes. Caseyville strata exposed along I-24 in the Goreville Quadrangle were similarly interpreted as distributary-channel, interdistributary, and overbank facies of river-dominated or high-constructive deltas (Jacobson 1987).

Some evidence, however, does not agree with fluvial-deltaic models. Heterolithic strata that constitute the bulk of the Wayside Member contain locally abundant marine fossils, along with sedimentary structures suggesting tidal flats: interference ripples, rill marks, and small load casts. In the I-57 roadcut, millimeter-scale ripples, "wrinkle marks," and possible mudcracks in thin bedded Wayside strata suggest very shallow water, perhaps intertidal (Erik Kvale, personal communication 1988).

Coals, carbonaceous shales, and rooted zones occur above and below the Buck Branch and Keller sandstones and in the interval between the Battery Rock and Pounds Sandstones. Coals and rooted zones occur in the same stratigraphic positions in quadrangles to the east, but all of these coals are lenticular (Jacobson 1991, Nelson et al. 1991). These strata

represent marsh or swamp deposits and are the only Caseyville rocks clearly not of marine origin.

The Buck Branch, Keller, Battery Rock, and Pounds sandstones have erosional lower contacts and basal conglomerates, as do basal Wayside sandstone lenses along I-57 and eastward (fig. 10). These sandstones evidently are channel deposits. Unidirectional, south- or southwest-dipping crossbedding in many exposures supports Ethridge and Jacobson's views that these are fluvial or distributary channel sands. However, bidirectional or multidirectional paleocurrents are indicated in places, particularly near the tops of sandstones and in areas where the sandstones are thin. For example, alternating thin-thick foreset laminae and interference ripple marks occur in the Pounds Sandstone along I-57 and suggest tidal influence (Erik Kvale, personal communication 1988). Also, the lack of clay matrix and good sorting of some of the sandstones suggest winnowing and reworking by tidal currents.

An alternative view of the big Caseyville sandstones is that they are estuarine sediments. The erosional surfaces on which they lie may have developed during regressions. As sea level rose again, incised valleys were drowned and became estuaries. The dominant currents in the estuaries were fluvial and down regional dip (toward the Ouachita trough); but bidirectional tidal currents also were active, especially in late stages of valley filling.

The Caseyville Formation is much thicker and contains thicker and coarser sandstones in the eastern half of the quadrangle. This thick Caseyville rests on some of the youngest preserved Mississippian rocks in the Illinois Basin. Hence, the thickness change probably reflects more rapid subsidence in the eastern part of the quadrangle. Structural mapping of the Kinkaid Limestone (Weibel and Nelson 1993) reveals no faults or sharp flexures. Thus, regional downwarp or tilting of the crust apparently was involved.

### **Tradewater Formation**

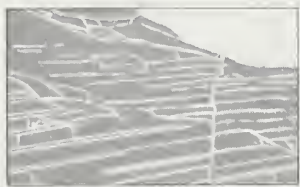
Sedimentation patterns similar to those of the Caseyville continued during deposition of the Tradewater Formation. The lower shaley member was deposited at least partly in shallow subtidal to intertidal settings not far from shore. Trace fossils

in the lower member in the I-57 roadcut are typical of brackish-water environments (Devera 1989), and the sedimentary structures suggest tidal action. However, thin coal beds in the lower member in the subsurface are evidence of terrestrial swamp conditions. The lower sandstone member in the I-57 roadcut contains tidal channel deposits (Kvale and Uhler 1988, Kvale and Archer 1991). Marine fossils in a drill core and intensely burrowed siltstone and sandstone in this member are further indicators of marine conditions. The overlying middle shaley member likewise contains burrows and other trace fossils. The equivalent olive shale in nearby quadrangles contains a distinctly marine assemblage of trace fossils (Devera 1989). The middle shaley member, however, also contains coaly shale with terrestrial plant fossils. The upper sandstone member in the Lick Creek Quadrangle lacks features diagnostic of particular depositional environments, although local bidirectional crossbedding and well winnowed quartz sands suggest estuarine or tidal settings for part of the member.

### **Quaternary Deposits**

The Glasford Formation was probably deposited by and from glaciers that entered north-trending valleys, as suggested by Lamar (1925). The dip-slope of Pennsylvanian sandstones in the Lick Creek Quadrangle presented the final barrier to southward advance of Pleistocene ice sheets. The Glasford probably includes sediment deposited in lakes that formed as the glaciers melted and dammed north-trending valleys (Willman and Frye 1980).

Superimposed drainage developed where Glasford sediments filled preglacial valleys. After the ice receded, north-flowing creeks meandered across the gently sloping Glasford surface but were unable to reoccupy their former channels. Cutting downward, the creeks encountered bedrock in places. Unable to migrate laterally, they eroded deep, sinuous, and meandering gorges into sandstone. Upstream from superimposed segments, the creeks aggraded, forming floodplains. Thick deposits of Glasford Formation along the sides of preglacial valleys remain as terraces. These terraces are gradually disappearing through gullying, creeping soil, and landsliding.



## STRUCTURAL GEOLOGY

The structure of the Lick Creek Quadrangle is simple. Paleozoic strata dip gently toward the northeast, as shown by structure contour lines on the geologic map (Weibel and Nelson 1993). The average dip of the Kinkaid Limestone decreases from about 100 feet per mile (1.9%) in the southwestern part of the quadrangle to about 80 feet per mile (1.5%) in the northeastern part. These dips are less than  $1^\circ$ . The strike of bedding changes from northwest to southeast in the southwest to west-northwest to east-southeast in the northeast. This gentle northeast dip is basically regional dip from the east flank of the Ozark Dome into the Illinois Basin (fig. 2).

J.M. Weller (1940, p. 12) mapped a feature called the Goreville anticlinal nose, extending from Section 32, T11S, R2E, northeastward into the Goreville Quadrangle. Weller based the anticline on elevation changes of lower Pennsylvanian sandstones. Our mapping and that of Jacobson (1991) shows that the Goreville anticline does not exist at the level of the Kinkaid Limestone, which has a northeast homoclinal dip. The structure of Pennsylvanian strata is difficult to map because sandstones are lenticular, bedding surfaces are not planar, and marker beds are absent. Because sandstones in the Caseyville Formation thicken near Goreville, the tops of these sandstones tend to rise because of differential compaction and produce the appearance of an anticlinal nose. J.M. Weller (1940) suggested that the Goreville anticline might be a product of "unequal original deposition" rather than tectonic deformation.

The only fault large enough to map in the Lick Creek Quadrangle is a small thrust fault exposed in an

abandoned sandstone quarry southeast of I-57 in the NE SW NW, Section 25, T11S, R1E. The fault strikes  $N60^\circ W$ , dips about  $25^\circ$  to the southwest, and displaces strata of the Wayside Member of the Caseyville Formation. Throw is about 10 feet, and net slip (assuming only dip-slip motion) is about 24 feet. Shale beds are folded and contorted in a manner consistent with reverse faulting. A thin zone of brecciated sandstone marks the fault plane. Rocks adjacent to the fault plane are moderately fractured and stained salmon pink. Slickensides and mineralization are absent.

The nearest major fault zone is the Ste. Genevieve Fault Zone, which is about 13 miles southwest of the thrust fault (fig. 2). The Ste. Genevieve strikes northwest and is composed of high-angle reverse faults whose southwest side is upthrown (Nelson and Lumm 1985). The trend and sense of movement of the small thrust fault are similar to those of the Ste. Genevieve Fault Zone, implying that the small fault may have developed under the same stress field as did the Ste. Genevieve.

A small fault, mapped by Lamar (1925) as striking northeast across Grassy Creek in Section 1, T11S, R1E, and Section 6, T11S, R2E, apparently does not exist. Sandstone beds in this area dip gently northeast, but do not appear to be offset.

Several faults too small to indicate on the geologic map occur in the study area. The best exposed examples are in the basal shale member of the Tradewater Formation in the roadcut along I-57 (fig. 18). These faults display listric surfaces that merge with bedding planes, downward rotation of layering in

the downthrown block (reverse drag), and thickening of strata on the downthrown block (small-scale growth faulting). Such features are typical of faults that developed during or shortly following deposition of the sediments.

Joints are common in sandstone outcrops in the study area and are shown on the geologic map. That most joint observations are in the western half of the quadrangle reflects differing propensities of the authors to record joint observations in the field, more than an actual westward increase in frequency and intensity of joints (although joints do appear to be more frequent to the west). Most joints are discontinuous, spaced several inches to several feet apart, and not mineralized. At no place in the quadrangle is jointing intense and pervasive. The most common orientations of joints are northeast to east-northeast and north-south to slightly west of north, but joints having other trends appear sporadically. The relationship of joints to other structures is unclear, and no regional synthesis of jointing has been attempted. Joints in the study area probably resulted from more than one tectonic episode.

To summarize, bedrock strata in the Lick Creek Quadrangle dip regionally northeast at an average rate of less than  $1^\circ$ . No significant folds or faults were mapped. A small, northeast-verging thrust fault, known from a single exposure, may be associated with the Ste. Genevieve Fault Zone. Other minor structures in the quadrangle probably formed during deposition and compaction of the sediments. Jointing is common, but nowhere intense, and its relationship to regional structure is obscure.



## ECONOMIC GEOLOGY

The principal geologic resource in the Lick Creek Quadrangle is limestone for construction and agricultural purposes. Slight potential exists for mining fluorspar, base metals, or coal. Nine unsuccessful petroleum-test holes have been drilled to upper Mississippian targets; deeper prospects remain untested.

### Limestone

Kinkaid Limestone has been quarried in the Lick Creek Quadrangle and used for aggregate, road rock, Portland cement, agricultural lime, and bituminous pavement (Lamar 1959). The Southern Illinois Stone Company operates a large quarry just southeast of the study area and quarries from the Goreville, Cave Hill, and Negli Creek Members of the Kinkaid. In the Lick Creek Quadrangle, quarries formerly operated in the Cave Hill Member in the S½ NE SE, Section 21, near the center of E½ NE, Section 29, and NW SE, Section 20, all in T11S, R1E. A small quarry in the Goreville Member was in the NW SW NW, Section 25, of the same township.

The thickness and lithologic succession of the Kinkaid appear to be consistent throughout the quadrangle, but undesirable components include shale interbeds and chert nodules. The thick intervals of shale at the top and base of the Cave Hill Member can be handled by quarrying the rock in benches, as is done at the Southern Illinois Stone Company quarry. Thus, given favorable economic factors, there is good potential for quarry development in the Kinkaid Limestone in the Lick Creek Quadrangle.

Other limestones of the Pope Group, such as the Menard Limestone and the Cora Limestone Member of the Clore Formation, are too thin or contain too many shale interbeds to be of likely commercial interest.

### Sandstone

Large amounts of sandstone are available in the Lick Creek Quad-

range, particularly in the Caseyville Formation. Thick intervals of nearly pure quartz sandstone occur in the Caseyville in the southeast quarter of the quadrangle. Although degree of cementation varies widely, Caseyville sandstones tend to be more resistant to weathering and abrasion than sandstones of the Pope Group or Tradewater Formation.

Lamar (1925) reported that sandstone from the Lick Creek area was formerly used for building stone, culverts, retaining walls, and water-well linings. Concrete and other materials have largely supplanted these uses of sandstone, and current demand for sandstone as a quarry product is small. The only recently-active sandstone quarry in southern Illinois is a small operation in the Waltersburg Quadrangle (Weibel et al. 1991) that produces flagstone for walkways and decorative siding.

An abandoned sandstone quarry was observed during mapping just east of I-57 in the W½ NW, Section 25, T11S, R1E. Thick bedded sandstone from the lower Wayside Member of the Caseyville, is exposed in the pit. The operator, dates of operation, and uses of the stone are unknown. Proximity to I-57 suggests that rock from this quarry was used as fill during highway construction in the 1960s.

### Fluorspar and Base Metals

The Lick Creek Quadrangle lies northwest of the Illinois-Kentucky Fluorspar District (fig. 2). Within the district, fluorspar occurs as vein deposits along faults and as bedded-replacement deposits associated with small faults or fracture zones. Although vein deposits occur along faults with upper Chesterian and Pennsylvanian wall rocks, economically minable deposits of both types are mostly confined to the interval from the St. Louis Limestone through the Cypress Sandstone (Grogan and Bradbury 1968). In the Lick Creek Quadrangle, these rocks occur at depths of 400 feet or greater.

The absence of traces of mineralization and of the type of structures associated with ores in the Illinois-Kentucky district imply that the Lick Creek Quadrangle is not a promising area for commercial deposits. However, Eidel and Baxter (1989) postulated on the basis of trace element studies that fluorite mineralization may occur in an area of southwestern Illinois that includes this quadrangle, and small fluorite-containing veins and vugs have been observed in the Ste. Genevieve Limestone at a quarry near Anna, about 6 miles southwest of the Lick Creek Quadrangle.

### Sand and Gravel

Prospects for commercial sand and gravel operations in this quadrangle are poor. Locally, material suitable for fill can be obtained from some of the larger creek beds in the area. Some medium to coarse grained, relatively uncemented quartz sandstone of the Caseyville Formation has potential as a source of silica for manufacturing amber glass bottles and as molding and sand-blasting sand (John M. Masters, written communication 1993).

### Clay and Shale

Shale and claystone units in the Caseyville and Tradewater Formations are a potential source of clay resources, most likely for manufacture of red-burning fired clay products such as common brick. Some claystone may be valuable as liners and covers for waste disposal. If fire-clay-type underclays occur in minable thicknesses, they would be usable as low-grade, high-plasticity refractory clay (Randall E. Hughes, written communication 1994).

### Coal

Coal in the Lick Creek Quadrangle has negligible potential for commercial exploitation. No record was found of any coal mining in the quadrangle, nor was any evidence of past mining observed during mapping. The thickest coal observed

in the study area is 1.1 feet thick, which is well below the minimum thickness for economic mining.

### **Petroleum**

Nine oil- and gas-test holes have been drilled in the quadrangle; all were dry and abandoned (table 1). A show of oil was reported in the Ste. Genevieve Limestone at 1,980 to 1,981 feet in the Monjeb Minerals no. 1 Throgmorton hole in Section 5, T11S, R2E. The deepest hole drilled to date is the Hildreth no. 1 Houston, which reached a depth of 2,109 feet in the Ste. Genevieve. Seven of the eight

remaining tests in the quadrangle reached the Ste. Genevieve; the Adams no. 1 Walker well terminated in the Chesterian Golconda Formation.

The nearest oilfields are the Energy and Marion fields, which are about 10 miles north of the quadrangle in T9N, R2E, Williamson County.

Evaluating petroleum resources of the Lick Creek Quadrangle is difficult. No structural features that could provide traps are known, but deep buried structures and stratigraphic traps created by up-dip pinchouts of reservoir rocks might

be present. A number of formations below the Ste. Genevieve that have yielded hydrocarbons elsewhere in the Illinois Basin are probably present here. They include the St. Louis, Salem, and Ullin Limestones (Mississippian), Dutch Creek Sandstone (Middle Devonian), Clear Creek Formation (Lower Devonian), and Galena (Trenton) Group (Middle Ordovician). The New Albany Shale (Devonian–Mississippian), which is 50 to 100 feet thick in this area, is an excellent source rock when within the oil maturation window (Barrows and Cluff 1984).

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## GEOLOGIC HAZARDS

Bedrock and surficial materials of the quadrangle generally provide stable conditions for construction projects. A few areas, however, are known to be unstable. Landslides have occurred along steep slopes underlain by the Glasford Formation, and some areas of limestone bedrock have developed karst features.

### Landslides

Numerous recent landslides have occurred along steep valley walls in the northern part of the report area, particularly along the north side of Grassy Creek in the S½, Section 25, T10S, R1E. These landslides involve un lithified sediment of the Glasford Formation.

During mapping, a house narrowly escaped destruction in a landslide. The house was built on Glasford sediments near the top of a steep slope on the north side of Grassy Creek, about 50 feet above stream level. The stream undercut the foot of the slope, triggering the landslide. The hillside below the house failed in a series of rotational slump blocks, forcing Grassy Creek to cut a new channel farther south. Gaping fissures appeared next to the foundation of the house (fig. 23), while uphill (north) of the house a graben 50 to 60 feet long and 10 to 12 feet wide was formed, damaging the driveway (fig. 24). An artificial pond just east of the house lost its water; this water possibly lubricated shear planes at the base of the landslide, thereby assisting the slide.

Numerous older landslides (possibly 10 to 50 years old) were observed in this area. Evidence for landslides includes hummocky topography, tilted trees, and scarps near the tops of steep slopes. Slides are most likely to occur when a creek undercuts the foot of a steep slope, especially when groundwater levels are high, the creek is high, and the toe of the slide is saturated.

### Karst

Karst topography is created by chemical dissolution of rocks by water. Limestone is especially prone to

karstification because it is soluble in even slightly acidic water. Typical karst features are enclosed depressions (sinkholes or dolines), caves, numerous large springs, and fluted rock outcrops (Ford and Williams 1989). Surface drainage is commonly disrupted and may be subordinate to underground drainage. Solution generally occurs along joints, which are common in southern Illinois. Water flowing along joints dissolves the rock and gradually widens the joint. Karstification begins in the subsurface and is not always evident at the surface. Sinkholes appear only when the roofs of subterranean passageways begin to collapse.

In the Lick Creek Quadrangle, karst features, including sinkholes,

springs, and fractures widened by solution, occur in the Menard, Clore, and Kinkaid Formations. In the thinner limestones of the Clore, only several small sinkholes were observed, but widened joints are common. The largest sinkholes are found in the Menard and Kinkaid Limestones, which contain the thickest intervals of limestone. Some sinkholes in the Kinkaid outcrop belt cover several acres and are more than 20 feet deep. In several cases, younger basal Pennsylvanian rocks exhibit karst features where they have collapsed into caves that developed in the underlying Kinkaid Limestone.

Aquifers in karstified bedrock are easily susceptible to contamination from the surface because the



**Figure 23** Tension fissure caused by a landslide on the north side of Grassy Creek. The creek is to the south (right) of the house.



**Figure 24** A graben created by a landslide on the north side of Grassy Creek. The view is to the east; the house to the right is the same house shown in figure 23. The scarp on the uphill side (left) apparently is the major glide plane of the landslide, whereas the scarp to the right represents an antithetic fault. The hazards of building on steep slopes underlain by the Glasford Formation are evident in this photo.

bedrock is so honeycombed by large passageways and karst aquifers tend to recharge more rapidly than other types of aquifers. Rapid recharge allows little time for physical, biological, and chemical breakdown of water-borne contaminants.

Karst areas may be unstable for construction because of (1) differential compaction of soil overlying an

irregular bedrock surface, (2) infiltration of surface water and soil piping, and (3) collapse of solution cavities (White 1988). In places, plugged sinkholes have caused flooding problems when structures were built below surface outflow elevations. No specific karst-related construction problems were observed in the Lick Creek Quadrangle during map-

ping; but in nearby areas, farm ponds constructed on karst have lost their water, and sinkholes appeared in a schoolyard at Dongola (Union County) in 1993 (Panno et al. 1994). Solutions to karst-related construction problems are available, but generally are expensive (Knight 1971, Sowers 1984, Wilson and Beck 1988, Destephen and Wargo 1992).



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