Paleozoic and Quaternary Geology of the St. Louis Metro East Area of Western Illinois

63rd Annual Tri-State Geological Field Conference
October 6–8, 2000

Rodney D. Norby and Zakaria Lasemi, Editors

ILLINOIS STATE GEOLOGICAL SURVEY
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ISGS Guidebook 32

Cover photo *Aerial view of Casper Stolle Quarry at the upper right, Falling Springs Quarry at the left, and the adjacent rural residential subdivision at the right, all situated at the northernmost extent of the karst terrain in St. Clair County, Illinois. Photograph taken April 7, 1988, U.S. Geological Survey, National Aerial Photography Program (NAPP1).*

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63rd Annual Tri-State Geological Field Conference
Sponsored by the Illinois State Geological Survey

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Foreword

The Illinois State Geological Survey welcomes you to the St. Louis Metro East area and the 63rd Annual Tri-State Geological Field Conference. This field conference provides the opportunity to examine some of the geologic features in this area. Because of time limitations, not all of the interesting geologic aspects of the area can be visited, but we hope that this guidebook and the cited references will point the way to additional features that can be examined at another time. Although the geology of the St. Louis Metro East area was extensively studied in the late 1800s and early 1900s, research tapered off over the last 40 years. In recent years, there has been a resurgence of research about the area, and this guidebook highlights some of it.

Acknowledgments

The success of any field trip requires the cooperation and assistance of numerous individuals, and this trip is no exception. We particularly want to thank three stone quarry companies for generous grants that helped to offset the student registration fees for this field conference:

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Middle Mississippian Carbonates in the St. Louis Metro East Area: Stratigraphy and Economic Significance

Zakaria Lasemi and Rodney D. Norby

On part of this field trip we will examine rocks representing the Meramecian Series (upper half of the Valmeyeran), the most widely exposed Mississippian series in the St. Louis metropolitan area on both sides of the Mississippi River (Fig. 1).This part of the guidebook will provide a general background for discussion and interpretation of the features that will be seen at several of the field trip stops. The Mississippian units that will be examined include the Warsaw Formation and the Salem, St. Louis, and Ste. Genevieve Limestones. The trip will focus on the stratigraphy and depositional facies of these units as seen in road cuts and quarries in the St. Louis Metro East area of Illinois. We will discuss litho- and biostratigraphic relationships, examine oolitic and bioclastic grainstone shoals and shoaling-upward cycles, and discuss sequence stratigraphic relationships.

Boundaries between the middle Mississippian carbonate and siliciclastic units have been placed differently by various workers. The resultant inconsistencies have caused confusion and some misinterpretation of stratigraphic relationships. Currently we are studying the regional stratigraphy and depositional facies of the middle Mississippian units in western Illinois. Our lithostratigraphic and biostratigraphic data, integrated with published information, have provided a useful framework for understanding regional stratigraphic and sequence stratigraphic relationships among these units.

We have recognized a number of key stratigraphic horizons within the Mississippian units in the field trip area and adjacent regions. Some of these horizons include (1) a discontinuity surface between the lower and upper Warsaw, (2) an unconformity at the Salem-St. Louis Limestone boundary, (3) a conodont faunal break accompanied by a change in lithofacies between the lower and upper St. Louis, (4) the "Lost River Chert" zone, a widespread bryozoan-rich chert and thin-bedded, bryozoan-rich lime mudstone and wackestone, and (5) the facies change accompanied by a change in the conodont fauna at the St. Louis-Ste. Genevieve Limestone boundary. During the field trip, we will discuss the significance of these horizons for understanding the middle Mississippian stratigraphy in the area and for interpreting the sequence stratigraphic relationships.

The Mississippian carbonates are economically important units in the Illinois Basin. They are excellent sources of construction aggregates and high-calcium limestones and contain hydrocarbon reservoirs in Illinois and adjacent states. A better understanding of stratigraphic and sequence stratigraphic relationships will help to delineate lateral and vertical variations in the thickness and quality of aggregate resources and factors that control hydrocarbon reservoir development.

Mississippian Units in Western Illinois

This section discusses the litho- and biostratigraphy of the Mississippian units that will be examined in the field trip area. On the basis of new information from our ongoing studies in the area, we have revised the stratigraphic boundaries between several Mississippian units, thus elucidating some of the sequence stratigraphic relationships. However, because of space limitations, sequence stratigraphy will not be covered in detail in this guidebook but will be discussed at various field trip stops.

Warsaw Formation

The oldest formation that will be observed during the first day of this trip is the Warsaw Formation (Hall 1857) or Warsaw Shale (Fig. 1). It occurs in western and southwestern Illinois, southeastern Iowa, and eastern Missouri. Rocks equivalent in age to the Warsaw are present in western Missouri, Kansas, Nebraska, and throughout the Illinois Basin (Lasemi et al. 1998). Facies analyses and biostratigraphic data suggest that the Warsaw is divisible into an upper and a lower interval (Kammer et al. 1990; this study). The lower part of the Warsaw is primarily a shale, whereas limestone and, in some areas, dolomite constitute a significant portion of the upper part of the Warsaw (Fig. 2; Stop 4).

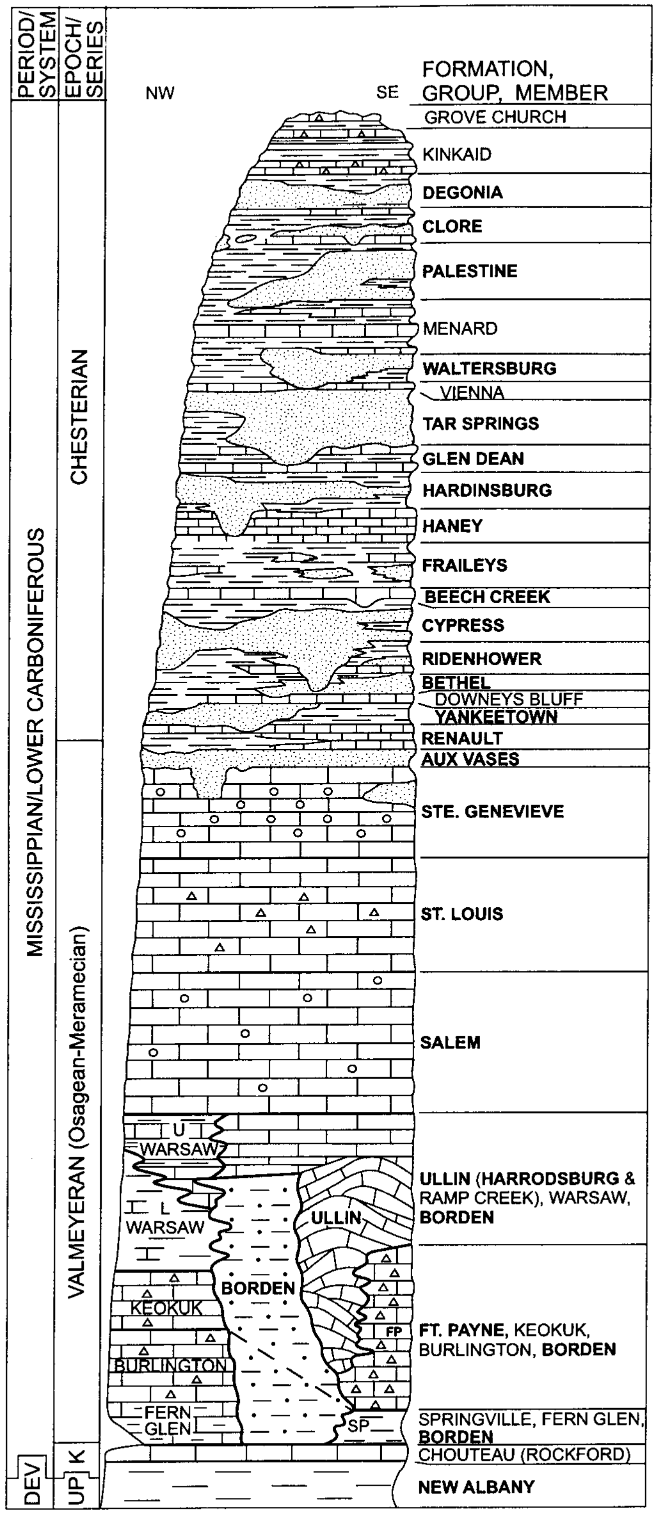


Figure 1 Generalized stratigraphic column (Mississippian) for Illinois. Formations or members that contain hydrocarbon pay zones are shown in bold type. Abbreviations: Devonian (DEV), Upper Devonian (UP), Kinderhookian (K), Fort Payne (FP), Springville (SP), lower (L), and upper (U). Variable vertical scale. (Modified from Lasemi et al. 1994).

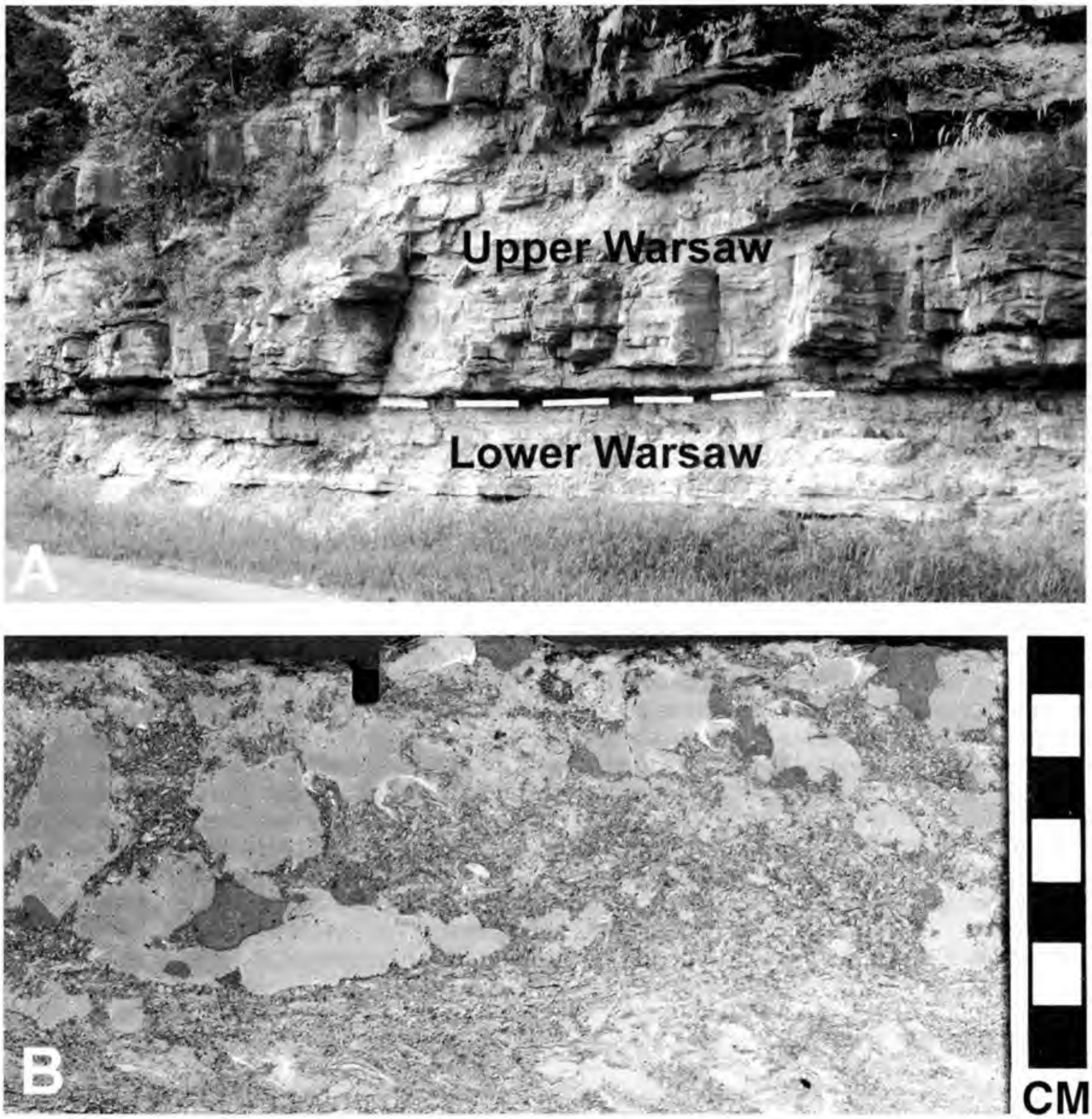


Figure 2 A. Lower and upper Warsaw Formation, Beltrees Road section, NE NE SW Sec. 13, T6N, R11W, Jersey County, Illinois, Elsah 7.5-minute Quadrangle. **B.** The intraclastic, pyritic, and phosphatic horizon that marks the lower-upper Warsaw boundary (dashed line in A).

Subdivision of Warsaw Formation The boundary between the upper and lower Warsaw has been placed at different horizons by different authors (Hall 1857, Hall and Whitney 1858, Ulrich 1904, Weller 1908, Van Tuyl 1925). Recent studies (Kammer et al. 1990) have characterized the Warsaw both lithologically and paleontologically and redefined its relationship to the Osagean-Meramecian boundary. Kammer et al. (1990) basically employed Van Tuyl's (1925) concept of a lower and upper Warsaw, except that the lower-upper Warsaw boundary was adjusted upward to the top of Hall's (1857) "magnesium limestone" rather than to its base. The separation into lower and upper Warsaw essentially places the thick shales, dolomitic shales, and argillaceous dolomites (often allied with the upper Keokuk) into the lower Warsaw and the poorly to moderately sorted, bioclastic grainstones and shaly limestones into the upper Warsaw. This general scenario extends from the type Warsaw area in Hancock County, Illinois, to the St. Louis metro area and appears to extend farther south to the Ste. Genevieve, Missouri, area (Kammer et al. 1990). The paleontologic change that occurs at the contact between the lower and upper Warsaw is chronostratigraphically significant. Kammer et al. (1990) have used this faunal change to mark the Osagean-Meramecian Series boundary.

Our ongoing study of the Warsaw in the outcrop and subsurface has revealed the presence of a disconformity surface near the lithologic and faunal change suggested by Kammer et al. (1990). This horizon occurs at or near the top of the shale-dominated interval of the lower Warsaw and is characterized by an intraclastic and phosphatic limestone with abundant pyrite and some glauconite (Fig. 2B). This apparent disconformity surface can be traced from the type Warsaw area in Hancock County, western Illinois, south to the St. Louis metro area and north into southeastern Iowa.

Prior to 1966, the Warsaw Formation included the limestone unit that underlies the Salem in the deeper parts of the basin (Lineback 1966). Lineback (1966) renamed the "Warsaw" of southern Illinois the Ullin Limestone and restricted the term Warsaw to the mixed carbonate-shale units (Warsaw Formation) in western Illinois. The upper Warsaw is similar and equivalent, at least in part, to the upper Ullin Limestone in southern Illinois (Kammer et al. 1990, Lasemi et al. 1998). The Ullin (Fig. 1) is a light-colored, crinoidal-bryozoan grainstone that ranges in thickness from 150 to 800 feet. At the Columbia road cut (Stop 4), the limestone that is thought to be part of the upper Warsaw (Kammer et al. 1990 and our studies) was assigned to the Ullin by Collinson et al. (1979). Because this limestone is closely associated with and interfingers with the shaly interval of the Warsaw, we think that the term upper Warsaw, rather than Ullin, should be used. In southern Illinois, where the shale is absent and the entire section is carbonate, the name Ullin is more appropriate.

Depositional environment Like the upper Ullin Limestone of southern Illinois, the upper Warsaw is primarily a poorly sorted and poorly rounded grainstone that is dominated by the remains of echinoderms (primarily crinoids) and bryozoans (Fig. 3A). Poor sorting and poor rounding of grains and the common presence of hummocky cross stratification in the upper Warsaw carbonates suggest rapid deposition perhaps in a storm-dominated environment. Similar conditions have been interpreted for deposition of the upper Ullin Limestone to the east in the Illinois Basin (Lasemi et al. 1994, 1998). Crinoidal-bryozoan bioherms, which were common during deposition of the Ullin Limestone (Lasemi et al. 1994, 1998), also were apparently present in some areas during deposition of the upper Warsaw (Lasemi and Smith 1999) and provided skeletal material for development of storm-deposited carbonate sand shoals. Both the Ullin and Warsaw grade into a better sorted and rounded, in part oolitic/pseudo-oolitic, grainstone in the uppermost part. The Ullin/upper Warsaw deposition ended with brief exposure and was followed by a regional transgression that resulted in deposition of the argillaceous, spiculitic, and siliceous limestone of the lower Salem (Lasemi et al. 1998).

Salem Limestone

The Salem Limestone (Cumings 1901) is a bioclastic limestone, in part oolitic to pseudo-oolitic, that is up to 500 feet thick in the central part of the Illinois Basin in southern Illinois (Cluff 1984). The unit generally ranges between 60 and 100 feet thick at the margin of the basin in western Illinois. The Salem (Fig. 1) overlies the Ullin Limestone in southern Illinois and the Warsaw Formation in western and southwestern Illinois. It is overlain by the St. Louis Limestone throughout the basin. In some areas in northwestern and west-central Illinois and southeastern Iowa, a fine-grained, greenish gray calcareous sandstone, the Sonora Sandstone (Keyes 1895), underlies and grades laterally into the Salem (Atherton et al. 1975).

The Salem Limestone in the St. Louis Metro East area consists of several cyclic sequences of shoaling-upward grainstone and tidally influenced lime mudstone (Lasemi et al. 1996, 1997). The grainstones are for the most part better sorted and more rounded (Fig. 3B) than the crinoidal-bryozoan grainstones in the upper Warsaw and Ullin (Fig. 3A). The bioclastic Salem Limestone contains abundant forams, peloids, and some green algae (Baxter 1960, Baxter and Brenckle 1982, Cluff 1984). The lower part of the Salem is a cherty, spiculitic, argillaceous and dolomitic limestone (Fig. 3C) that regionally overlies the Ullin/upper Warsaw in the Illinois Basin. In southwestern Illinois and Ste. Genevieve County, Missouri (see back cover), the Salem is mainly a crinoidal, bryozoan, peloidal grainstone in the lower part (Fig. 4A) and an oolitic to pseudo-oolitic, foraminiferal grainstone in the upper part (Fig. 4B). Our petrographic data indicate that the lower

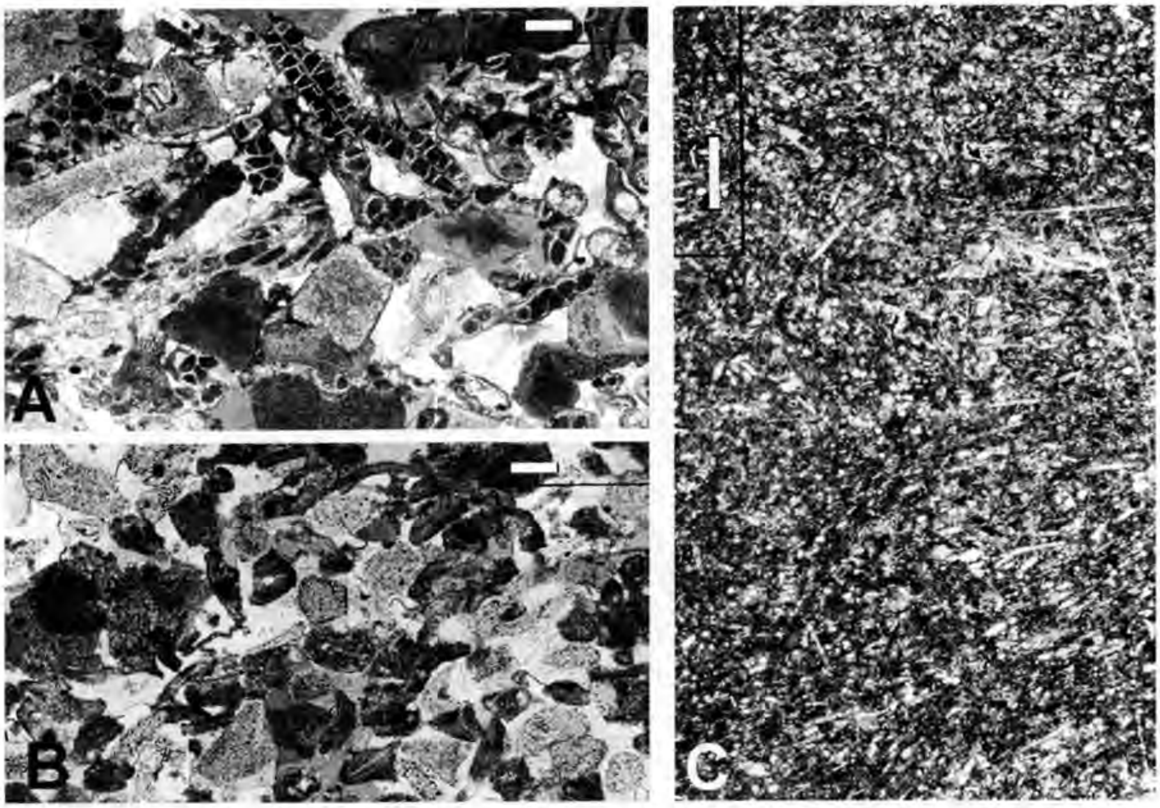
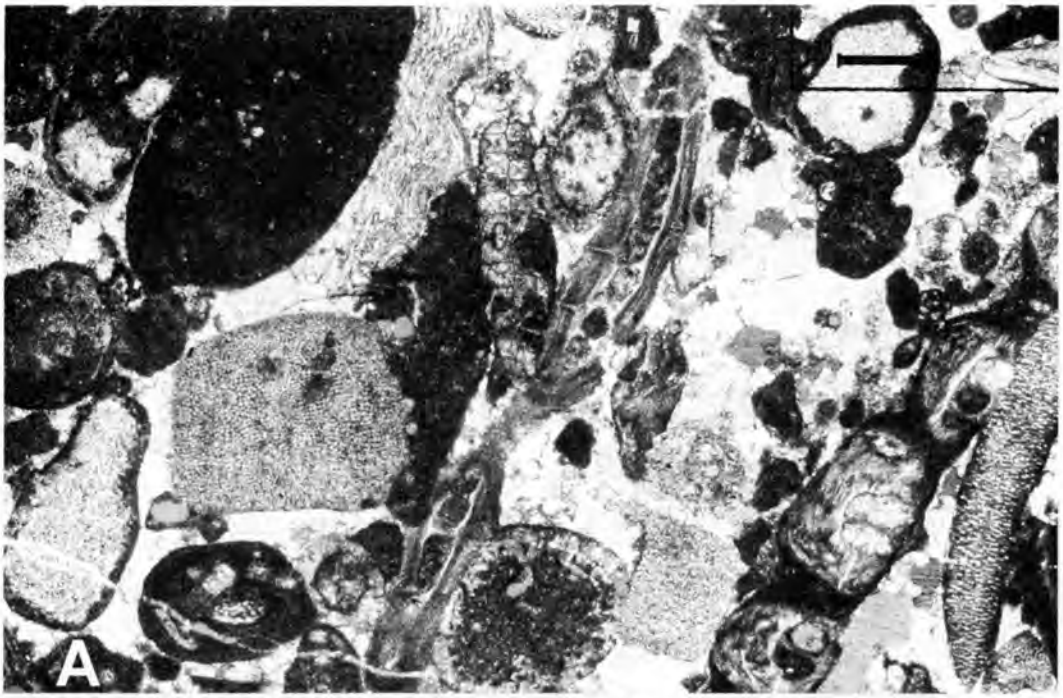


Figure 3 Thin-section photomicrographs (cross-polarized light) from Columbia road cut (Stop 4). **A.** Upper Warsaw (unit 21, Fig. 32), note poorly sorted echinoderm and bryozoan fragments. **B.** Moderately sorted, crinoidal-bryozoan grainstone of the Salem (unit 3, Fig. 32). **C.** "Fults" Member of the Salem (unit 12, Fig. 32); note common sponge spicules (needle-shaped particles). Bar scales = 0.5 mm.

part of the Salem in these areas is lithologically similar to the entire Salem in the St. Louis Metro East area.

The Salem Limestone has been the subject of several studies. Major studies of the Salem in the subsurface of the Illinois Basin include those by Lineback (1972), Keller and Becker (1980), Cluff and Lineback (1981), and Cluff (1984). Baxter (1960, 1965) studied the general facies and economic importance of the Salem Limestone in the western Illinois outcrop belt. He subdivided the Salem in Monroe, Randolph, and St. Clair Counties, southwestern Illinois, into four members, which in ascending order include: (1) the Kidd, a crinoidal-bryozoan grainstone; (2) the Fults, an argillaceous, cherty, laminated, and silty limestone with some bioclastic limestone; (3) the Chalfin, largely a fine-grained limestone, in part oolitic to pseudo-oolitic and pelletal, in part sublithographic and brecciated; and (4) the Rocher, a fine to coarse, bioclastic, partly oolitic grainstone with microfauna similar to those of the Chalfin and lower St. Louis. Because of lithologic similarities to the Ullin Limestone, Lineback (1966) assigned most of the Kidd Member to the upper Ullin Limestone (Harrodsburg Member). We basically concur with Lineback (1966), but currently think that all of the Kidd should be included with the Ullin Limestone of southern Illinois or the upper Warsaw in the St. Louis-Prairie du Rocher-Ste. Genevieve area. The Kidd represents the last phase of Ullin/upper Warsaw deposition that was ended by a regional transgression marked by relatively deep water facies of the lower Salem ("Fults" and its lateral equivalents). We have found that recognition of the Salem members as defined by Baxter (1960) is difficult beyond the type sections in southwestern Illinois. These members appear to us to be depositional facies, which roughly correspond to the shoaling-upward cycles commonly seen within the Salem in the subsurface (Cluff 1984) in southern Illinois and in the outcrop belts in western Illinois (Lasemi et al. 1996, 1997).

Depositional environment Cluff (1984) investigated the depositional facies of the Salem in the subsurface. He recognized up to four shoaling-upward cycles within the Salem in the southern



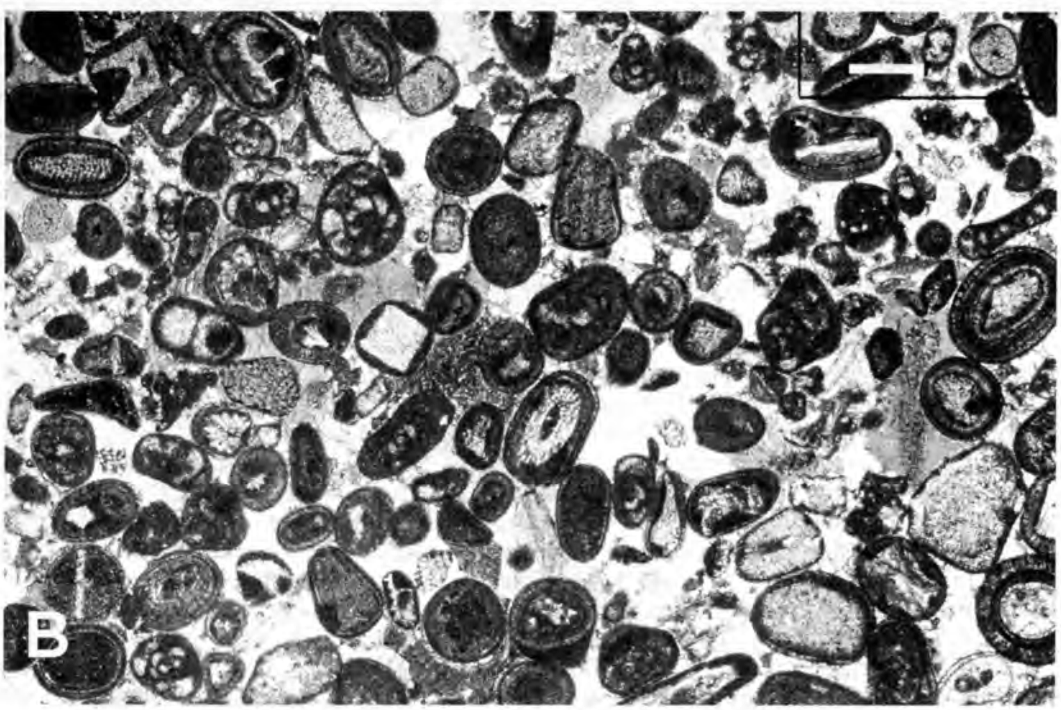


Figure 4 Thin-section photomicrographs (cross-polarized light) of the Salem Limestone from Ste. Genevieve County, Missouri. **A.** Lower Salem intraclastic, crinoidal-bryozoan grainstone, bar scale = 0.25 mm. **B.** Upper Salem foraminiferal, oolitic grainstone; bar scale = 0.5 mm.

Illinois subsurface (Fig. 5). Cluff (1984) suggested that toward the margins of the basin (including western Illinois), the Salem grades into a fine-grained, restricted facies that generally lacks the typical shoaling-upward cycles seen in the subsurface. However, we have identified similar, but thinner cycles within the Salem in the outcrop belts in western Illinois (Lasemi et al. 1996, 1997). The number of cycles in the Salem has recently been used as a predictive tool in assessing limestone quality and reserves in several quarries in western Illinois (Lasemi et al. 1996, 1997, Wolf

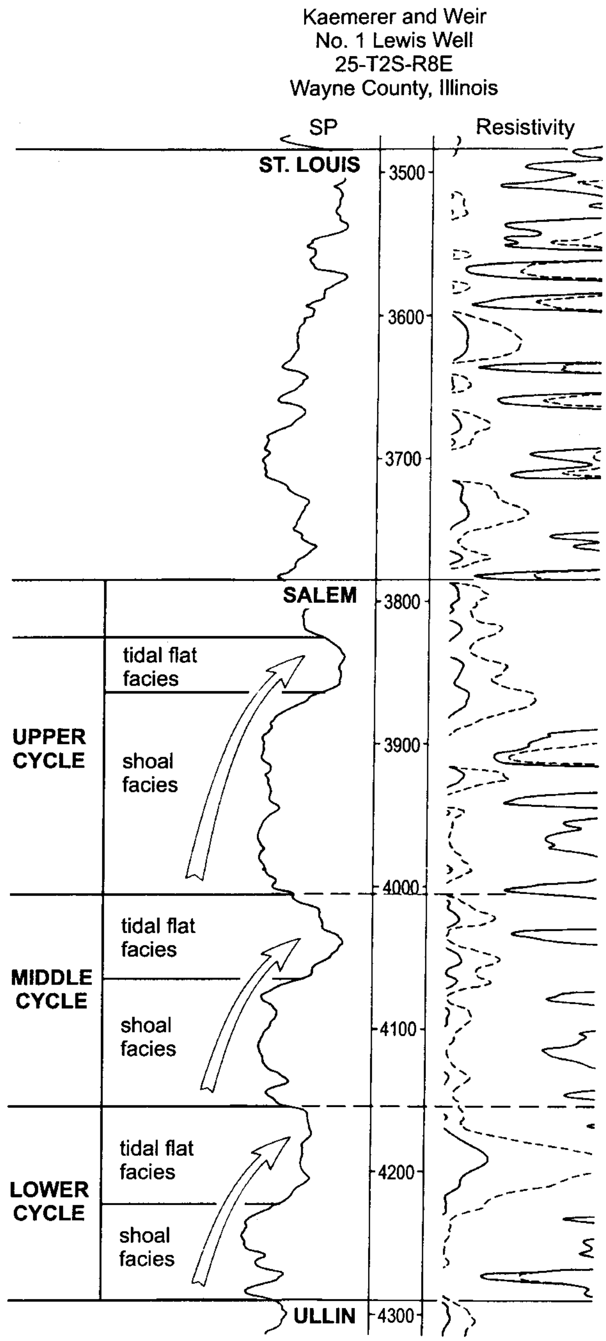


Figure 5 Geophysical log character of shoaling-upward cycles in the Salem Limestone (modified from Cluff 1984).

1997). Because the cycles are thinner there, they cannot be easily recognized at the resolution provided by the standard petroleum industry geophysical logs.

In western Illinois, a typical cycle consists of (1) a very thin transgressive conglomeratic unit (Fig. 6); (2) a relatively thick shoal facies consisting of a dense, high-calcium limestone, a bioclastic grainstone; and (3) a thin intertidal facies consisting of argillaceous lime mudstone and dolomite (Fig. 6). The intertidal facies in places contains tidal and stromatolitic laminations. A bioclastic wackestone and lime mudstone representing an open marine subtidal facies may underlie the grainstone shoal facies in some areas. In geophysical logs (Fig. 5), the argillaceous tidal flat facies of the cycle shows a positive spontaneous potential and high gamma ray responses, whereas the clean, grainstone

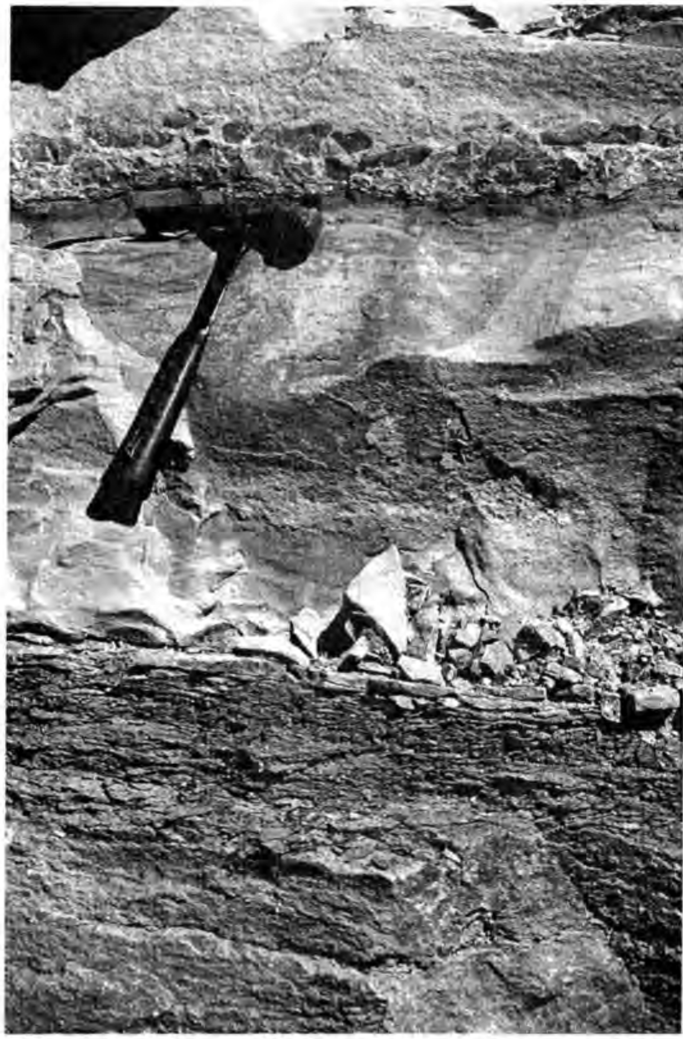


Figure 6 A section of the Salem from Columbia Quarry Company's Plant No. 1, NE Sec. 10, T1S, R10W, St. Clair County, Illinois, Columbia 7.5-minute Quadrangle, showing part of the intertidal-supratidal facies of an individual shoaling-upward cycle, overlain by the grainstone shoal facies of the next cycle. Note intraclasts above hammer head represent a transgressive surface at the base of the grainstone shoal facies.

shoal facies of the cycle shows a negative spontaneous potential and very low gamma ray responses. Each Salem cycle represents a shoaling-upward (shallowing-upward) sequence formed as a result of fluctuations in relative sea level or lateral migrations of contemporaneous environments within a single depositional system.

Ullin/Warsaw-Salem boundary The contact between the Warsaw Formation and the overlying Salem Limestone generally has been considered gradational. However, published data and new information based on our work suggest that an unconformity marks the boundary between the Warsaw and Salem in the outcrop belt. Weller and Sutton (1948) reported that the Salem, or the laterally equivalent, Sonora Sandstone (Keyes 1895), unconformably overlies the Warsaw Formation in northwestern Illinois and southeastern Iowa. In Adams County, Illinois, a possible unconformity, marked by a basal conglomerate, occurs in the middle of the carbonates overlying the lower Warsaw shale (Weller and Sutton 1948, p. 813). Weller and Sutton (1948) suggested that this unconformity was equivalent to the unconformity that occurs beneath the Salem in southeastern Iowa. A major brecciated and conglomeratic horizon also overlies the upper Warsaw crinoidal-bryozoan grainstone (now a fossil-moldic dolomite) in a quarry in southeastern Iowa (Lasemi and Smith 1999). In central Pike County, Illinois, major erosion apparently removed the Warsaw and underlying Keokuk prior to deposition of the Salem, and the Salem rests directly on the Burlington Limestone (Coryell 1919, p. 93).

We have identified a potential subaerial exposure surface at the upper Warsaw-Salem boundary in an abandoned quarry in Schuyler County, Illinois. This surface is characterized by an oxidized, undulatory surface overlain by a brecciated interval with possible laminated crusts. In some areas in western and southern Illinois and in Ste. Genevieve County, Missouri, the contact appears to be a discontinuity surface marked by a hardground (Fig. 7). Elsewhere, the upper Warsaw-Salem boundary is marked by a change in lithofacies from that of a shallow water limestone in the upper Warsaw to a silty, spiculitic, *Zoophycos*-bearing, argillaceous deeper water limestone at the base of the Salem (Stop 4; Fig. 3C). A similar, relatively deep-water facies that we interpret to be equivalent to the Somerset Shale at the base of the Salem in Indiana and Kentucky (Benson 1976) overlies the Ullin in much of the southern Illinois subsurface (Lasemi et al. 1998).

St. Louis Limestone

The St. Louis Limestone (Fig. 1; Englemann 1847, Ulrich 1904) in the Illinois Basin predominantly consists of fenestral, pelletal, and peloidal limestone; algal limestone (oncolite and stromatolite); bioclastic wackestone/packstone and some grainstone; microcrystalline dolomite; gypsum and anhydrite; limestone breccia beds, chert and siliceous limestone. Fine-grained, lithographic limestone can be quite common in some intervals (Atherton et al. 1975) but is not necessarily the dominant lithology as generally perceived. Gypsum and anhydrite are commonly present in the lower part of the St. Louis in the subsurface (Krumbein 1951, McGregor 1954, Saxby and Lamar, 1957, McGrain and Helton 1964, Dever and McGrain, 1969, Diaby and Carozzi 1984), but are generally confined to shelf areas at the margin of the basin. In and close to the outcrop belts, no gypsum or anhydrite beds have been found, but several breccia beds that occur in the lower part of the St. Louis have been related to collapse of the overlying limestone layers after dissolution of gypsum and anhydrite beds (Collinson et al. 1954, Collinson and Swann 1958).

Depositional environment Pinsak (1957, p. 23–24) divided the St. Louis of Indiana into two parts on the basis of lithology. The lower part is composed of dense brown carbonaceous limestone that alternates with units of gypsum and anhydrite and interbeds of black, gray, and greenish shale. This lithology indicates a period of restricted water circulation during deposition of the lower St. Louis Limestone. The upper part of the St. Louis is micritic, pelletal, and skeletal limestone, representing a return to a more open marine environment. Similar lithology with a restricted marine limestone facies in the lower part and an open marine facies in the upper part also characterizes the unit equivalent to the St. Louis in southeastern Iowa (Croton Member of the "St. Louis", Witzke et al. 1990) and southeastern Kentucky (Pohl 1970). Microfacies analysis of the St. Louis Limestone in Illinois, Indiana, and Kentucky (Diaby and Carozzi 1984) also revealed that a widespread restrictive environment prevailed during the early stages of St. Louis deposition.

In the St. Louis Metro East area, the lower and upper parts of the St. Louis Limestone are also lithologically distinct, and the boundary at which the change in facies occurs corresponds to the conodont break reported by Rexroad and Collinson (1963; see next section). In these areas, we have found that the lower St. Louis is characterized by a nearshore restricted marine facies (Fig. 8) consisting of pelleted and fenestral lime mudstones, algal limestone (oncolitic and stromatolitic; Fig. 9A), collapsed breccia beds, and microcrystalline dolomites. Mudcracks are also present in some of the lime mudstone facies (Fig. 9B). Southward from Waterloo, the restricted marine facies of the St. Louis grades into an open marine facies. Farther south in parts of Monroe and Randolph Counties, southwestern Illinois, and in Ste. Genevieve County, Missouri, the restricted marine facies of the lower St. Louis grades into an open marine shallow shelf facies characterized by oolitic to pseudo-oolitic, foraminiferal grainstone of the upper Salem (Fig. 4B) interpreted by Weller and St. Clair (1928) and Baxter and Brenckle (1982) to be equivalent to the lower St. Louis in the St. Louis Metro East area. We interpret the upper Salem in these areas to represent a ramp margin grainstone belt. Behind this belt a restricted marine lagoon and tidal flat environment developed where the restricted marine facies of the lower St. Louis was deposited (Fig. 8). The rocks of the

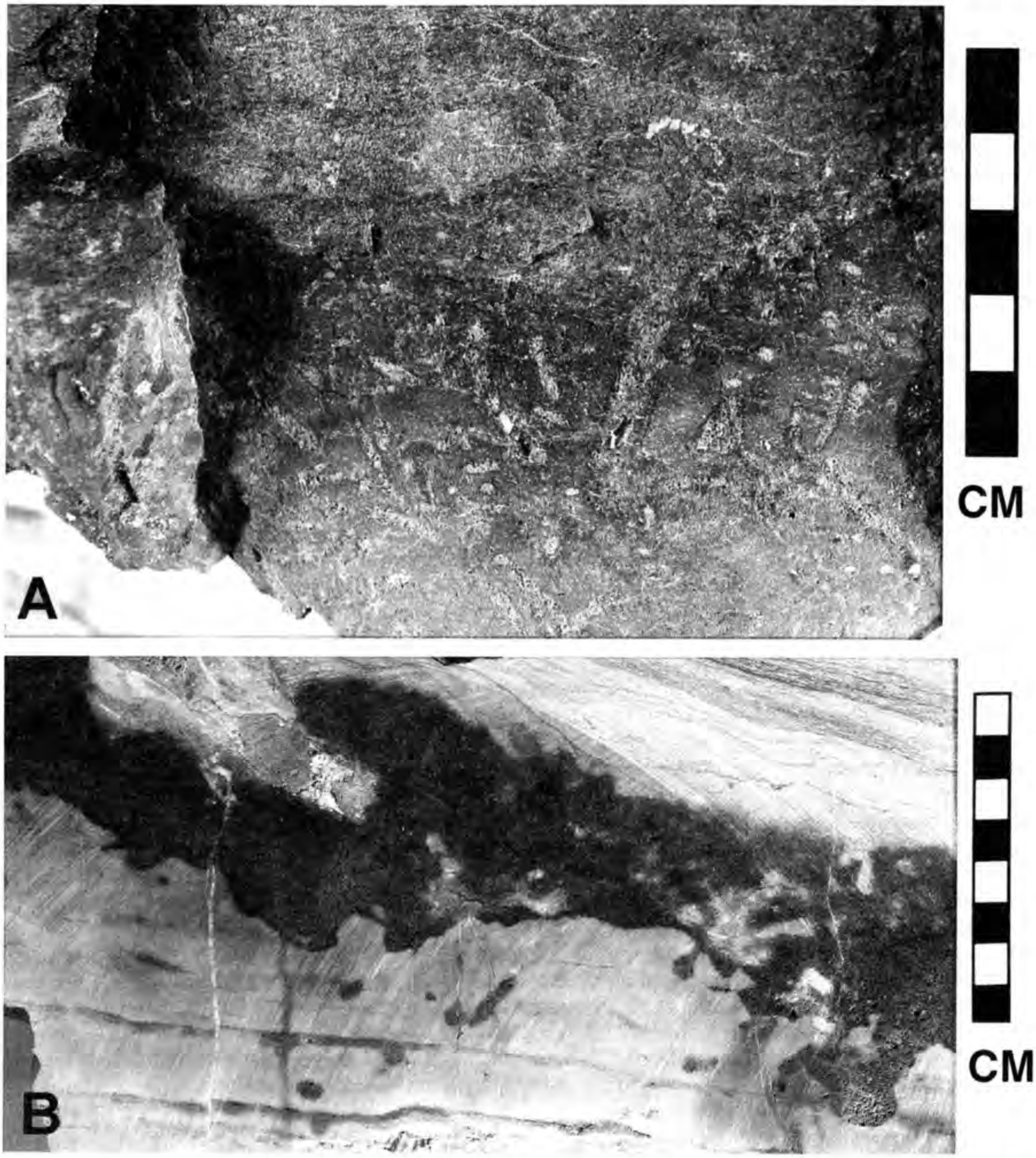


Figure 7 Cross section through the burrowed discontinuity surface (hardground) at the Warsaw-Salem boundary. **A.** Tower Rock Stone Company Quarry, Sec. 7, T38N, R9E, Ste. Genevieve County, Missouri, Prairie du Rocher 7.5-minute Quadrangle. **B.** Lohr quarry, SE Sec. 5, T6N, R10W, Madison County, Illinois, Alton 7.5-minute Quadrangle.

ramp margin grainstone belt grade seaward farther south into siliceous, spiculitic, cherty lime mudstone and wackestone in the deeper part of the basin (Fig. 8).

The upper St. Louis in the field trip area is characterized by bioclastic wackestone/packstone, lime mudstone, and some bioclastic-peloidal grainstone. These rocks, which reflect a return to normal marine conditions, form a transgressive facies that onlaps the upper Salem-lower St. Louis from southern Monroe and part of Randolph Counties, Illinois, and Ste. Genevieve County, Missouri, northward into the St. Louis metro area. The onset of this transgression ended the restricted conditions that existed during the deposition of the lower part of the St. Louis.

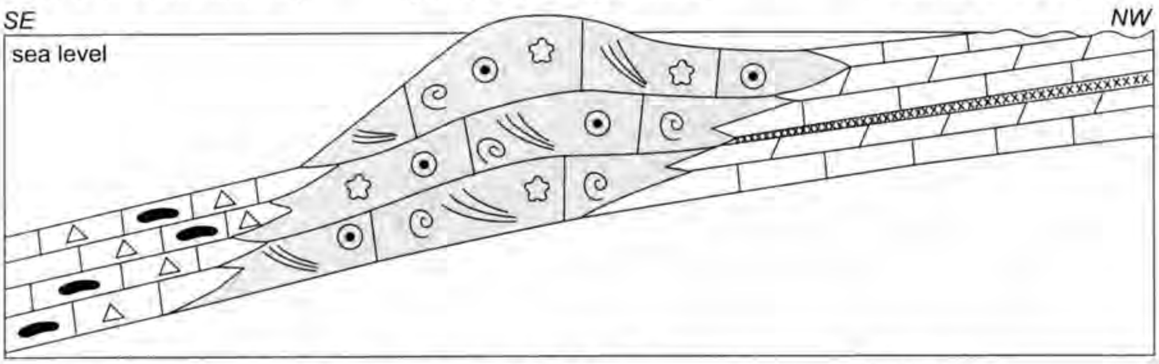


Figure 8 Idealized depositional model showing the relationship between the upper Salem and lower St. Louis (not to scale).

Subdivision of St. Louis Limestone A twofold subdivision of the St. Louis Limestone was first alluded to by Weller and St. Clair (1928) and later by Collinson et al. (1954) and Collinson and Swann (1958). A distinct conodont break occurs at the boundary between the lower and upper St. Louis (Rexroad and Collinson 1963). The regional conodont zone *Taphrognathus-Apatognathus* Assemblage Zone (unrevised) that typifies the Salem and the lower part of the St. Louis changes to the *Apatognathus scalenus-Cavusgnathus* Assemblage Zone (unrevised) in the upper part of the St. Louis (Rexroad and Collinson 1963, 1965). The latter zone ends at the end of St. Louis deposition and aids in the determination of St. Louis-Ste. Genevieve boundary (Norby and Lasemi 1999). In the St. Louis Metro East area, the upper and lower St. Louis boundary has been placed a short distance above the main breccia in the middle of the St. Louis (e.g., Collinson and Swann, 1958). Southward from the Columbia area, the breccia beds are not present, and the distinction between the lower and upper St. Louis is less clear. However, we have identified a light greenish gray, argillaceous limestone and/or shaly bed (up to 4 feet thick) that occurs at or just above the lower-upper St. Louis boundary in the St. Louis Metro East area (Stop 1). This bed is a key marker that can be traced from the Alton area to as far south as Ste. Genevieve County, Missouri.

Salem-St. Louis boundary The position of the contact between the Salem and the overlying St. Louis has been controversial. The base of a cherty lime mudstone and/or the appearance of the first bioclastic grainstone have been arbitrarily used to separate the Salem from St. Louis, especially in the subsurface. Numerous workers (Weller and St. Clair 1928, Weller et al. 1948, Collinson et al. 1954, Collinson and Swann 1958, Baxter and Brenckle 1982) have commented on or showed, based on lithologic character and micro- and macrofossils, that the upper part of the Salem in southwestern Illinois and in the Ste. Genevieve area, Missouri, is equivalent to the lower part of the St. Louis in the St. Louis Metro East area. On the basis of electric log cross sections, Lineback (1972) suggested that the upper part of the Salem on the northwest slope of the Illinois Basin (Monroe and Randolph Counties) lithologically graded laterally into the lower part of the St. Louis in the Metro East area (particularly in Madison County, Illinois). Cluff (1984) suggested that the grainstone facies of the Salem graded northward into a fine-grained tidal flat facies similar to that in the St. Louis Limestone.

New information from our ongoing study tends to support these interpretations regarding lateral gradation between the upper Salem and lower St. Louis. However, our data indicate that the lower St. Louis is equivalent to the upper Salem only in the area south of Waterloo, Illinois, in the Renault-Prairie du Rocher-Ste. Genevieve area. Conodont data indicate that the lower-upper St. Louis boundary, which occurs in the middle of the St. Louis Limestone in the St. Louis Metro East area, occurs at the Salem-St. Louis boundary in the Ste. Genevieve area, corroborating foraminiferal data by Baxter and Brenckle (1982). We have also identified a persistent unconformity

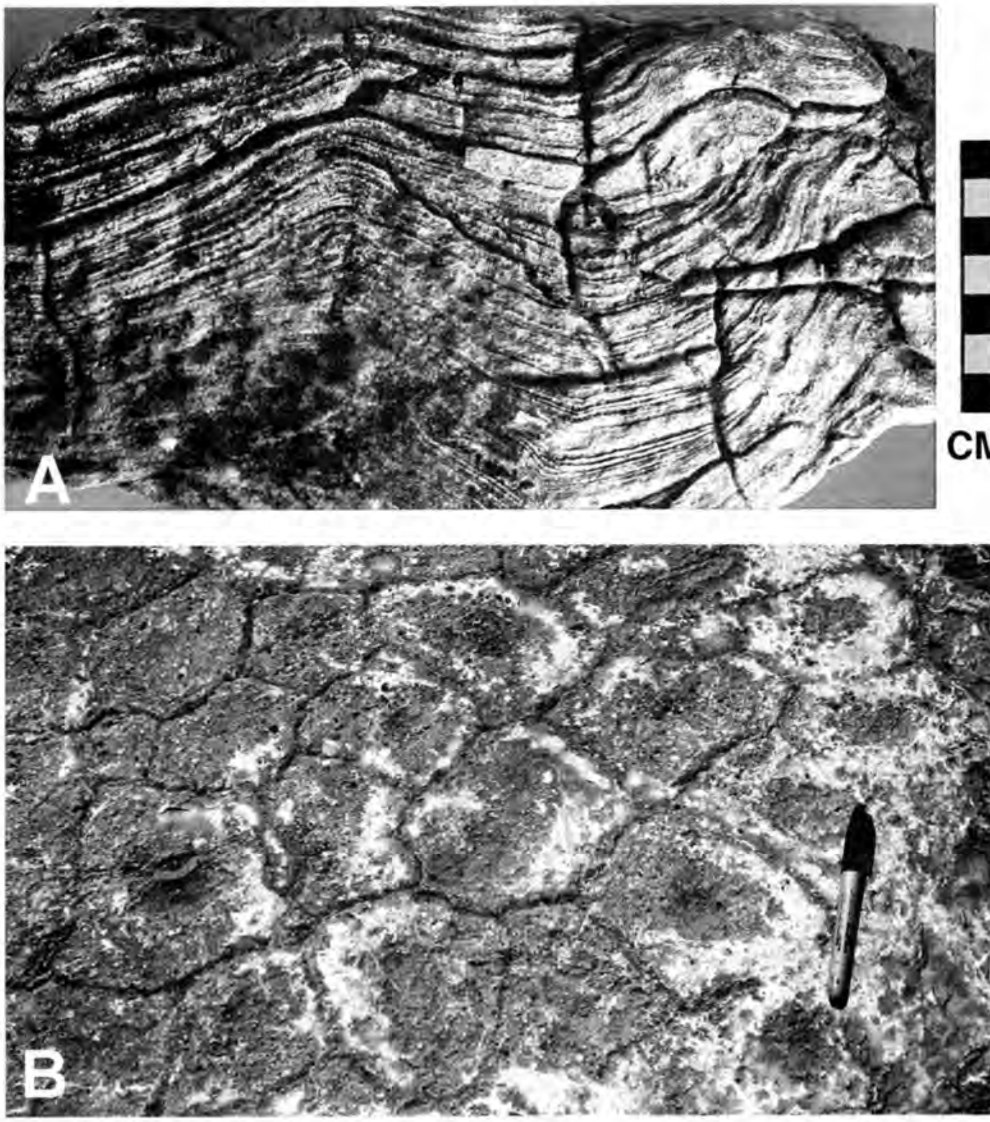


Figure 9 A. Naturally etched cross section through stromatolitic laminations, lower St. Louis, type Warsaw locality, NW NW Sec. 10, T4N, R9W, Warsaw 7.5-minute Quadrangle, Hancock County, Illinois. **B.** Plan view of mud cracks, lower St. Louis, Columbia Quarry Company's Plant No. 1, NE Sec. 10, T1S, R10W, St. Clair County, Illinois, Columbia 7.5-minute Quadrangle; 5-inch pen for scale.

characterized by a karstic and/or erosional surface at the Salem-St. Louis contact in the Metro East area (Fig. 10). Based on foraminiferal ranges, Baxter and Brenckle (1982) also alluded to the possible presence of a local hiatus between the Salem and St. Louis in the St. Louis metro area. An unconformity at a similar stratigraphic position was also reported by Weller and Sutton (1948, p. 815) from northwestern Illinois. Likewise, we have found an unconformity within the Salem in a core from near Renault, Monroe County, Illinois. Petrographically, the rock below this unconformity is similar to the Salem in the St. Louis Metro East area. The rock above the unconformity consists of shoaling-upward, oolitic, peloidal, foraminiferal grainstone (Fig. 4B). We think that this unconformity, which lies within the Salem in the Renault-Prairie du Rocher-Ste. Genevieve area (see back cover), is equivalent to the unconformity we have seen at the Salem-St. Louis boundary in the St. Louis Metro East area. If correct, these correlations indicate to us that the entire Salem in the Metro East area is equivalent to the lower Salem, and the lower St. Louis in the Metro East area is equivalent to the upper Salem in the Renault-Prairie du Rocher-Ste. Genevieve area, a conclusion supported by the biostratigraphic data.

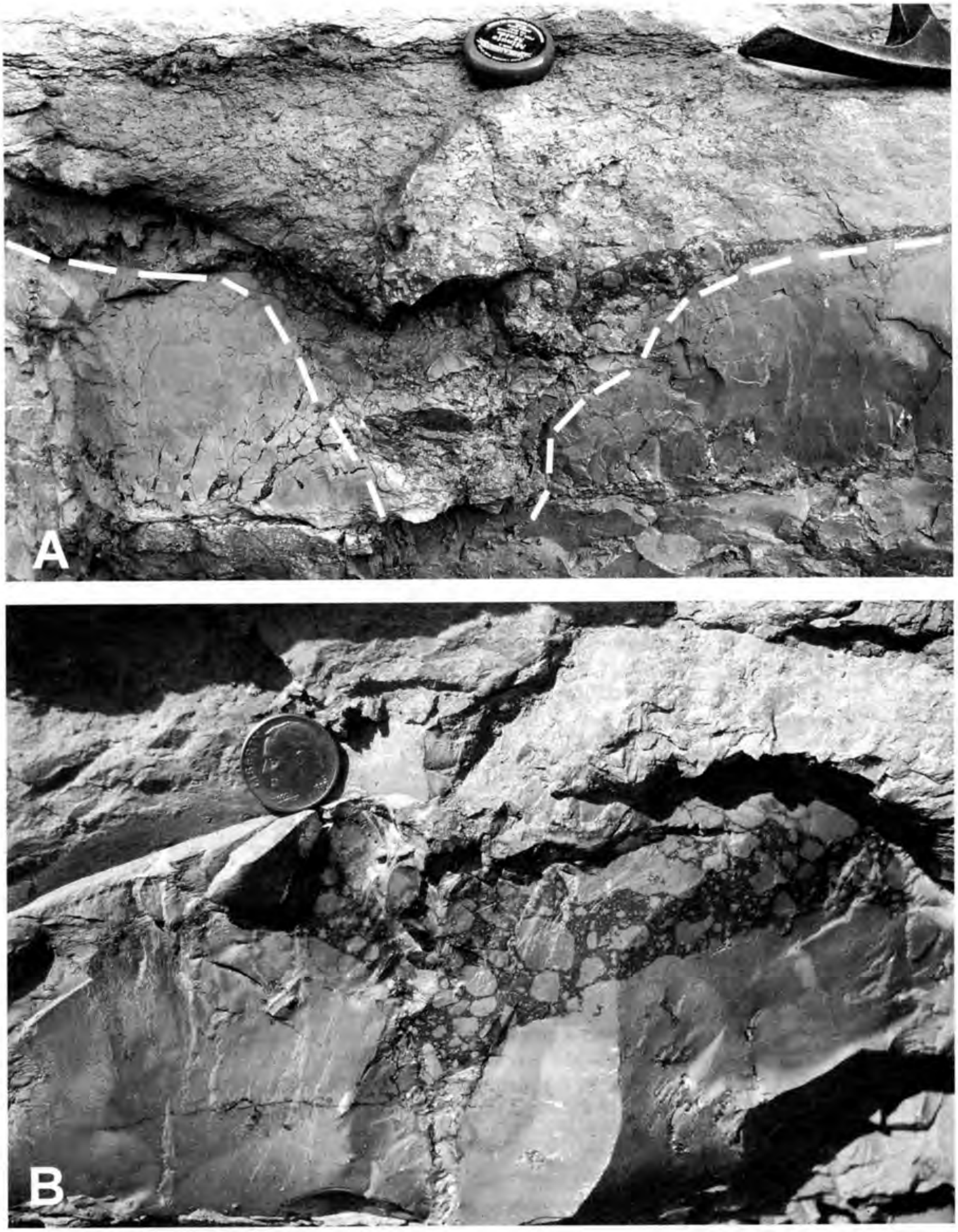


Figure 10 Cross section through paleokarstic surface at the Salem-St. Louis boundary, Waterloo quarry, NW and NE Sec. 8, T3S, R9W, Paderborn 7.5-minute Quadrangle, Monroe County, Illinois. **A.** An overall view; note prominent solution channel at center of photo, 1.3-inch bottle cap for scale. **B.** Close view of the brecciated surface and a solution fissure; 0.7-inch coin for scale.

Ste. Genevieve Limestone

The Ste. Genevieve Limestone (Fig. 1; Shumard 1860) occurs only sporadically at the top of some bluff sections in the St. Louis Metro East area (Collinson et al. 1954, Atherton et al. 1975). Here the limestone is typically an arenaceous, oolitic grainstone with varying amounts of fossiliferous shaly limestone, dolomitic limestone, lime mudstone, and some bioclastic grainstone interbeds (Stops 1 and 5). Elsewhere in the basin, the Ste. Genevieve Limestone contains well-developed oolitic grainstone deposited as irregular banks, linear sand bars, and tidal bar belts (Carr 1973, Choquette and Steinen 1980, Cluff 1984). The Ste. Genevieve Limestone has been one of the most prolific hydrocarbon producers in the Illinois Basin.

St. Louis-Ste. Genevieve boundary As an aid to recognizing the St. Louis-Ste. Genevieve boundary in Indiana, Rexroad et al. (1990) utilized the Lost River Chert Bed (LRCB), which generally appeared a few feet below the top of the St. Louis. The LRCB (Elrod 1899) is a distinct and regionally widespread stratigraphic marker that occurs in the uppermost part of the St. Louis Limestone around the basin (Pohl 1970, Woodson 1982, Rexroad et al. 1990). The LRCB is a cream to red to black, generally irregular to blocky chert with abundant bryozoans and some brachiopods and corals. An abrupt change in the conodont fauna also occurs at the top of the LRCB. In Illinois, Indiana, and Kentucky, the upper St. Louis fauna includes *Synclydognathus geminus*, whereas the Ste. Genevieve includes *Hindeodus cristulus* (Collinson et al. 1971, Rexroad et al. 1990). This abrupt change, covering a wide geographic area, implies a major hiatus at the St. Louis-Ste. Genevieve boundary (Rexroad et al. 1990). Along with conodont and lithologic criteria, the LRCB is a very reliable marker that has helped to establish the position of the St. Louis-Ste. Genevieve boundary in these areas. In the St. Louis Metro East area, we have identified a chert-bearing interval at about the same horizon near the top of the St. Louis (see Stops 1 and 5). This zone is a thin-bedded, bryozoan-rich lime mudstone to wackestone with some bioclastic packstone to grainstone. It generally contains from one to several chert beds, including one that we believe to be equivalent to the LRCB. The LRCB has not formally been recognized in the metro area, and until we can verify specific beds, we have informally named the entire interval, the Lost River Chert (LRC) zone (Norby and Lasemi 1999).

The LRC zone is irregular in thickness in the St. Louis metro area. possibly because of truncation at the St. Louis-Ste. Genevieve unconformity. The presence of an unconformity at the St. Louis-Ste. Genevieve boundary has also been reported from Ste. Genevieve County, Missouri (Weller and St. Clair 1928). In places in the Ste. Genevieve area, the St. Louis beds are truncated, and a conglomeratic horizon occurs at the St. Louis-Ste. Genevieve boundary. Elsewhere, solution fissures that occur below the St. Louis surface are filled with sediments from the overlying Ste. Genevieve (Weller and St. Clair 1928). For the Alton Bluff Section (Stop 5), Collinson et al. (1954) also reported the presence of vertical fissures several feet deep at the top of the LRC zone that were filled with sediment from the overlying Ste. Genevieve Limestone.

Conodonts indicative of the upper St. Louis are common in the LRC zone and are succeeded by Ste. Genevieve conodonts in beds above the LRC zone. In addition to the change in the conodont fauna, the contact here marks a change from a clean, bioclastic lime mudstone and wackestone in the LRC zone below to shaly, silty, argillaceous, sandy, oncolitic limestone above. In the St. Louis Metro East area, the top of the LRC zone marks the contact between the St. Louis and the Ste. Genevieve Limestone.

Previously, in western Illinois, the St. Louis-Ste. Genevieve Limestone boundary was assigned to a 35-foot "transition zone," where the lithologic and paleontologic characteristics of the two formations appeared to be mixed (Collinson et al. 1954). The occurrence of the LRC zone near the top of this "transition zone," the change in conodont fauna, and revised macrofossil ranges all show that most of the "transition zone" belongs to the St. Louis with only a few feet assigned to the Ste. Genevieve (see Stop 5 for details).

Economic Significance

The middle Mississippian carbonates are important sources of crushed stone and high-calcium limestone in western Illinois and adjacent areas. Porous and permeable intervals within many of these units form prolific hydrocarbon reservoirs in the Illinois Basin. Some of these units (e.g., the Salem and Ullin) are excellent sources for high-calcium limestone used for lime production, environmental remediation, and other industrial applications. Construction and maintenance of roads and buildings rely heavily on the local availability of inexpensive high-quality stone resources (Lasemi et. al. 1996, 1997). The St. Louis metro area contains significant amounts of stone reserves, but these are shrinking because of rapid development and urbanization.

Detailed descriptions of local and regional facies and regional stratigraphic analyses currently underway in the area are important in understanding lateral and vertical variations in the thickness and quality of aggregate resources. Facies analyses are useful in predicting the quality and reserves of minable stone. As an example, we have used the cyclicity (shoaling-upward cycles) revealed by facies analysis within the Salem Limestone to predict the quality and remaining reserves in several and quality will optimize output, reduce exploration cost, and help environmentally responsible development and expansion of existing mines and quarries.

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Structural Geology of the St. Louis Metro East Area

Joseph A. Devera and F. Brett Denny

A structurally complex monoclinal feature, the Lincoln Anticline and Cap au Grès Faulted Flexure, affects the Paleozoic rocks in the St. Louis Metro East area (Fig. 11). The Cap au Grès in the northern part of the Metro East area has an easterly trend, but it bends to the southeast at Deer Lick Hollow (Fig. 12) near the confluence of the Illinois and Mississippi Rivers. Southeast of Deer Lick Hollow, the structure is concealed beneath the Mississippi River alluvium, and the Mississippi takes a sharp turn eastward, apparently to follow the Cap au Grès Faulted Flexure. It returns to its general southward flow direction at the eastern extent of this feature (Fig. 11). At its west end, the Cap au Grès merges with a northwesterly trending anticline, the Lincoln Anticline. The term Cap au Grès is normally applied only to the steeply dipping and faulted southwest limb of the Lincoln Anticline, which has also been called the Lincoln Fold. The Florissant Dome is a medial structure between the Cap au Grès and the Waterloo-Dupo Anticline (Fig. 12). The Florissant feature bends to the south-southeast and is probably disrupted by the St. Louis Fault Zone (Frank 1948). The structure continues to the south-southeast where it is called the Waterloo-Dupo Anticline. The whole faulted fold complex is monoclinal with the south and west limbs being the steep sides. Early workers thought that each of the aforementioned features was a separate structural feature (Rubey 1952, Cole 1961). However, in order to maintain a balanced structural offset, Harrison (1993) interpreted these structures as a single system.

Geologic History

The geology of western Illinois has been influenced by the periodic uplift of the Ozark Dome, the Sangamon Arch, the Sparta Shelf, the Lincoln Anticline or Cap au Grès Faulted Flexure and the Waterloo-Dupo Anticline. The Ozark Dome has been an upland surface since Late Cambrian or earlier (no earlier age dating available) with intermittent Paleozoic seaway inundations. It is composed primarily of granite and rhyolite and forms a high of Precambrian rocks to the south named the St. Francois Mountains. Cambrian and Ordovician units in Missouri and Illinois thin toward the St. Francois Mountains, indicating that this feature has had positive relief since at least Late Cambrian time. The Sparta Shelf also was a positive surface during Cambrian sedimentation because the Cambrian Mt. Simon Formation is thin or absent in this area (Nelson 1995). During Late Ordovician, the Ozark Dome may have undergone slight uplift as shown by deposition of the Thebes Sandstone in southwestern Illinois and southeastern Missouri. Ordovician rocks in the area are diverse and include sandstones, carbonates, siltstones, and shales.

Silurian sedimentation was dominated by carbonates and shales to the south, but in the Metro East area, the Silurian rocks have been altered to dolomites. By late Early to Late Silurian, pinnacle reefs had begun to form along the margins of the shelf area separating deeper water deposits from the shallow environment. Silurian sediments, while absent in western Madison County, thicken rapidly to the east, attaining a thickness of over 500 feet in eastern Madison County (Willman and Atherton 1975). Northwest of Grafton in western Madison County, several feet of Middle Devonian Cedar Valley Limestone can be observed at a few isolated outcrops (see pages 43, 44; Fig. 17, Stop 7). These are the only Devonian rocks exposed in the area.

Lower Mississippian rocks (Kinderhookian and Valmeyeran) unconformably overlie Devonian through Ordovician rocks. Late Mississippian through early Pennsylvanian was a time of major deformation in the area as the Cap au Grès Faulted Flexure and the Waterloo-Dupo Anticline were active (Nelson 1995). The structures have steep dips on the south or west limbs and gentle dips of less than 4° on their north or east limbs. Most researchers agree that these structures were produced by reverse faulting of a Precambrian basement block and draping of the sedimentary cover (Rubey 1952, Tikrity 1968, Nelson and Lumm 1985). By the end of the Mississippian Period, a fall in relative sea level produced a subaerial exposure across Illinois. In the Belleville area, recent mapping has detected a local erosional surface with nearly 70 feet of relief on the top of the Mississippian rocks. The erosional surface was filled with sands and silts as a valley-fill sequence during the Pennsylvanian.

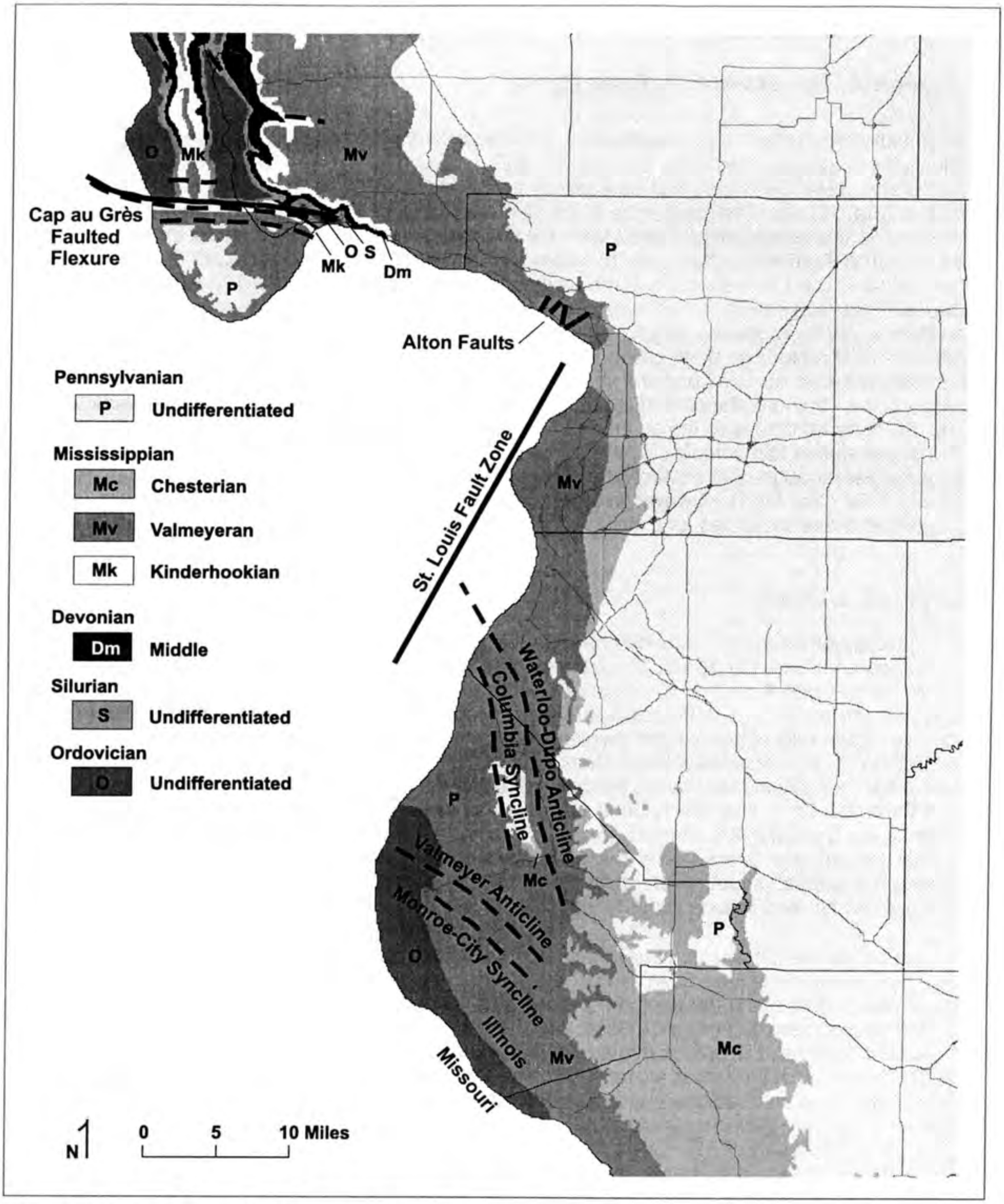

Figure 11 Geologic map of field trip area in western Illinois. Bedrock geology modified from Illinois Geographic Information System, volume 1, May 1996.

Tectonic Relationships

Ozark Dome

The Ozark Dome is a Precambrian high that has influenced the deposition of sediments throughout the area. Early Paleozoic rocks thin toward this structure, indicating its prolonged existence as a

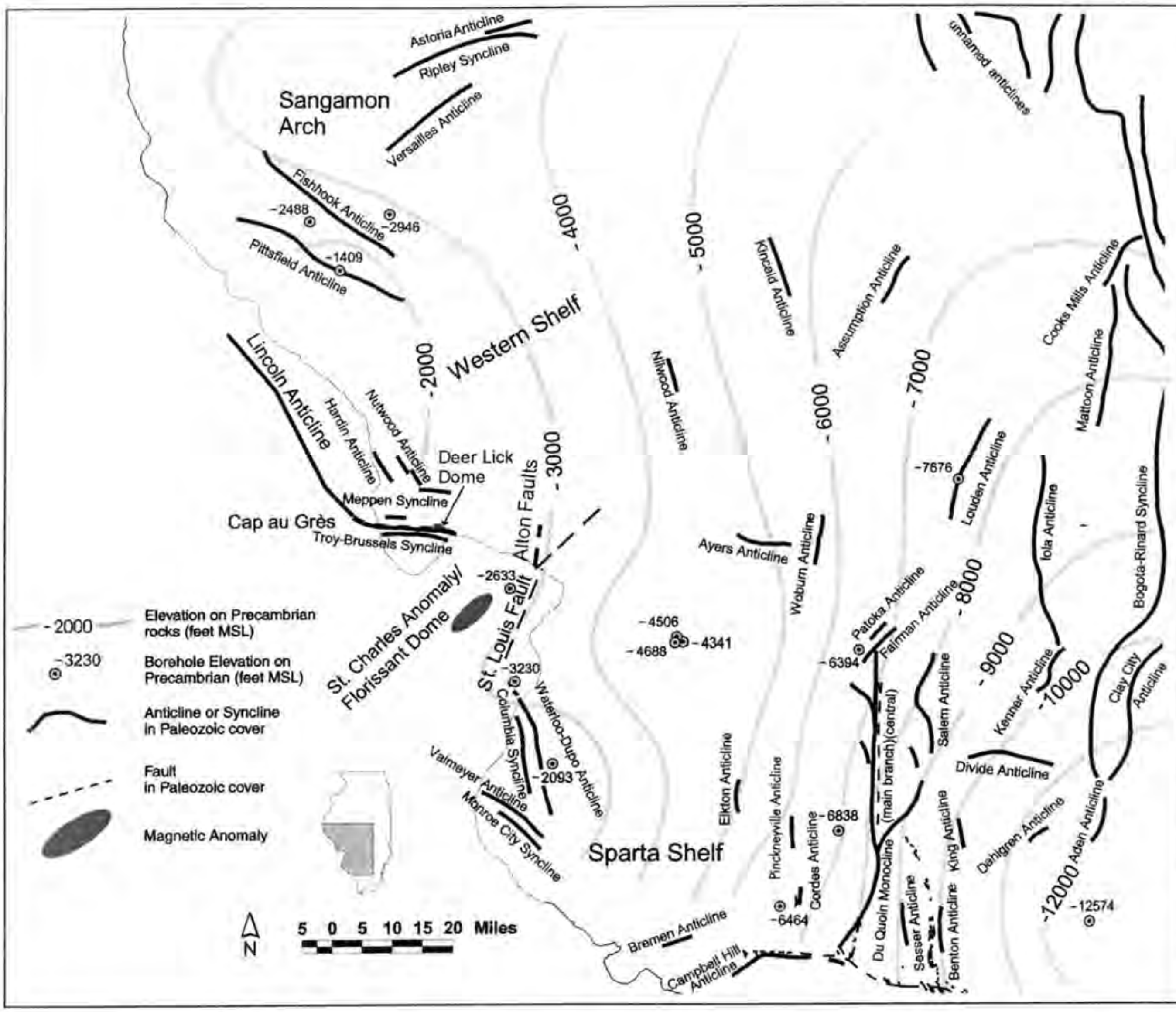

Figure 12 Structural features of west and west-central Illinois (modified from Nelson 1995).

structural prominence. Although this dome was undoubtedly a structural high, there is little evidence that it was ever a major source of clastic material to the Illinois Basin. The Ozark Dome was an area of low relief during much of Paleozoic history and was completely buried or nearly covered by Middle Devonian sediments. Devonian alkalic igneous intrusions occur in southeastern Missouri within the domal complex and indicate that the dome may have been rising at that time. The few wells in the area that reach the Precambrian basement indicate relatively steeper slope on crystalline basement eastward than northeastward into the Illinois Basin. Two wells, cited by Harrison (1993), penetrated the Precambrian basement in Missouri at –3445 feet and –2649 feet mean sea level. In Illinois, several wells have penetrated the basement surface (Fig. 12).

Lincoln Anticline/Cap au Grès Faulted Flexure

The most plausible explanation for the Cap au Grès feature was offered by Rubey (1952), Tikrity (1968), Nelson and Lumm (1985), Harrison (1993), and Nelson (1995). All of these authors discuss the possibility of a deep-seated reverse fault in the Precambrian basement. The Cap au Grès resembles monoclinal drape folds found on the Colorado Plateau that formed in sedimentary strata overlying reactivated basement faults (Harrison 1993). Nelson and Lumm (1985) compared the Cap au Grès Faulted Flexure with Laramide monoclines in the Rocky Mountains and Colorado Plateau where folds in sedimentary cover overlie faults in the Precambrian crystalline basement (Nelson 1995). The authors concur that the primary displacement along the structure is probably related to deep-seated reverse movement along a Precambrian basement block.

The timing of the Lincoln Anticline/Cap au Grès event is weakly constrained by broad stratigraphic relationships. We suggest that the structure was active starting in post Middle Devonian time and continuing sporadically through the earliest Pennsylvanian. No evidence for the Tertiary or younger faulting suggested by Rubey (1952) has been observed during recent mapping efforts in this area.

Waterloo-Dupo Anticline

This asymmetrical anticline, with a steep westerly dipping limb, has an axis that trends slightly west of north. In places, the western limb has dips greater than 45°, but the eastern limb has dips of only 2–4°. The structural style of this anticline is similar to the Salem and Louden Anticlines, and the La Salle Anticlinorium in Illinois and is probably a result of drape folding over a buried basement fault (Nelson 1995). Thinning of Silurian and Devonian units indicates that the basement fault was active during the Late Devonian. The major deformation took place prior to the Pennsylvanian because Desmoinesian units (Pennsylvanian) unconformably overlie Chesterian units (Mississippian).

Summary

The general alignment of tectonic structures parallel to the basement structure contours (Fig. 12) suggests a connection between these Paleozoic structures and basement faulting. Locally, some small anticlines and synclines may have formed by differential compaction and drape over buried Precambrian bedrock highs, similar to the drape structures located over Silurian pinnacle reefs, but the larger structures clearly resulted from regional compressional stress. Ongoing detailed geologic mapping in the area is helping to define its regional structural history.

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Quaternary Geology of the St. Louis Metro East Area

David A. Grimley

The St. Louis Metro East area (Fig. 13A) provides an important setting for the study of Quaternary geology because the region includes the confluence of three major rivers (Mississippi, Illinois, and Missouri Rivers) and the margin of two major glaciations (Illinoian and pre-Illinoian glacial stages). This advantageous position allowed for a rich record of Quaternary deposits, contrasting in age, lithology, source, and depositional environment. One of the unique aspects of the area is the domination of loessal and other silt deposits, which mainly originated from the broad Mississippi-Missouri Valleys that drained the entire Upper Midwest and Great Plains during the last several glaciations. The interspersal of loessal deposits between direct glacial deposits (till and sorted sediments) on uplands allowed for excellent preservation and separation of many key litho- and pedostratigraphic units. The combination of thick loess deposits with generally non-erosive glacial deposition near the terminal margin of the Laurentide Ice Sheet was fortuitous, since this also allowed for better preservation of easily recognizable and traceable layers in the geologic record. Furthermore, the wide expanse of postglacial floodplain in the American Bottoms area (Fig. 13B) contains within it an abundance of archeological sites (Milner 1998) and a high quality geologic record of the midcontinent during the late Holocene. Thus, St. Louis Metro East area Quaternary deposits have the potential for unearthing unusual finds and clues as to the paleoclimate and paleoenvironment of the past 500,0000 years.

Because of the societal needs of a growing metropolis, the St. Louis Metro East area has been the focus of several 7.5-minute quadrangle geologic mapping projects by the ISGS in the last few years (funded by the U. S. Geological Survey STATEMAP program). Although many new findings were discovered during the surficial geologic mapping in the area, the geology and geomorphology of the region have also been discussed by several previous researchers. Some of the previous studies and data sources for the area are outlined below, followed by a general geologic history of the area, as currently understood.

Background and Data Sources

American Bottoms

The American Bottoms, an extensive floodplain of the Mississippi River that contains many lakes and swamps, lies mainly on the Illinois side of the Mississippi River (Fig. 13B). Physiographic divisions in the American Bottoms have been noted by Yarborough (1974); Hajic (1990, 1993) has described landform sediment assemblages in the northern portion of the American Bottoms and the lower Illinois Valley. The environmental setting and geomorphology of the Mississippi River floodplain have also been discussed by Gladfelter (1979), White et al. (1984), and Milner (1998), who reconstructed some of the former paths of the Mississippi River in historical and late Holocene times. An abundance of data on shallow materials (typically down to 5 to 15 feet deep) is available from archeological projects along interstate routes (Kolb 1997, Booth and Koldehoff 1999) and soil survey parent material data (Fehrenbacher and Downey 1966, Goddard and Sabata 1982, Higgins 1984, Wallace 1978), which reflect sediments to depths of about 3–5 feet. The Illinois Department of Transportation, U. S. Army Corps of Engineers (Smith and Smith 1984), and many consulting companies in the area (e.g., Philip Services Corp., Geotechnology Inc., Shively Geotechnical Inc.) contributed to deep boring data. Groundwater resources and environmental contamination in the American Bottoms were investigated by Bergstrom and Walker (1956) and Rehfeldt (1992).

Upland Areas

Surficial geology of the uplands has been the subject of several theses and ISGS reports. Much of the early work in the area was summarized on a regional scale by Willman and Frye (1970). The Wisconsinan loess stratigraphy of the region was studied in detail by McKay (1977), with emphasis on the carbonate mineralogy, and by Grimley (1996) and Grimley et al. (1998), with emphasis on magnetic properties and silt mineralogy. McKay (1979) also provided a framework for Illinoian

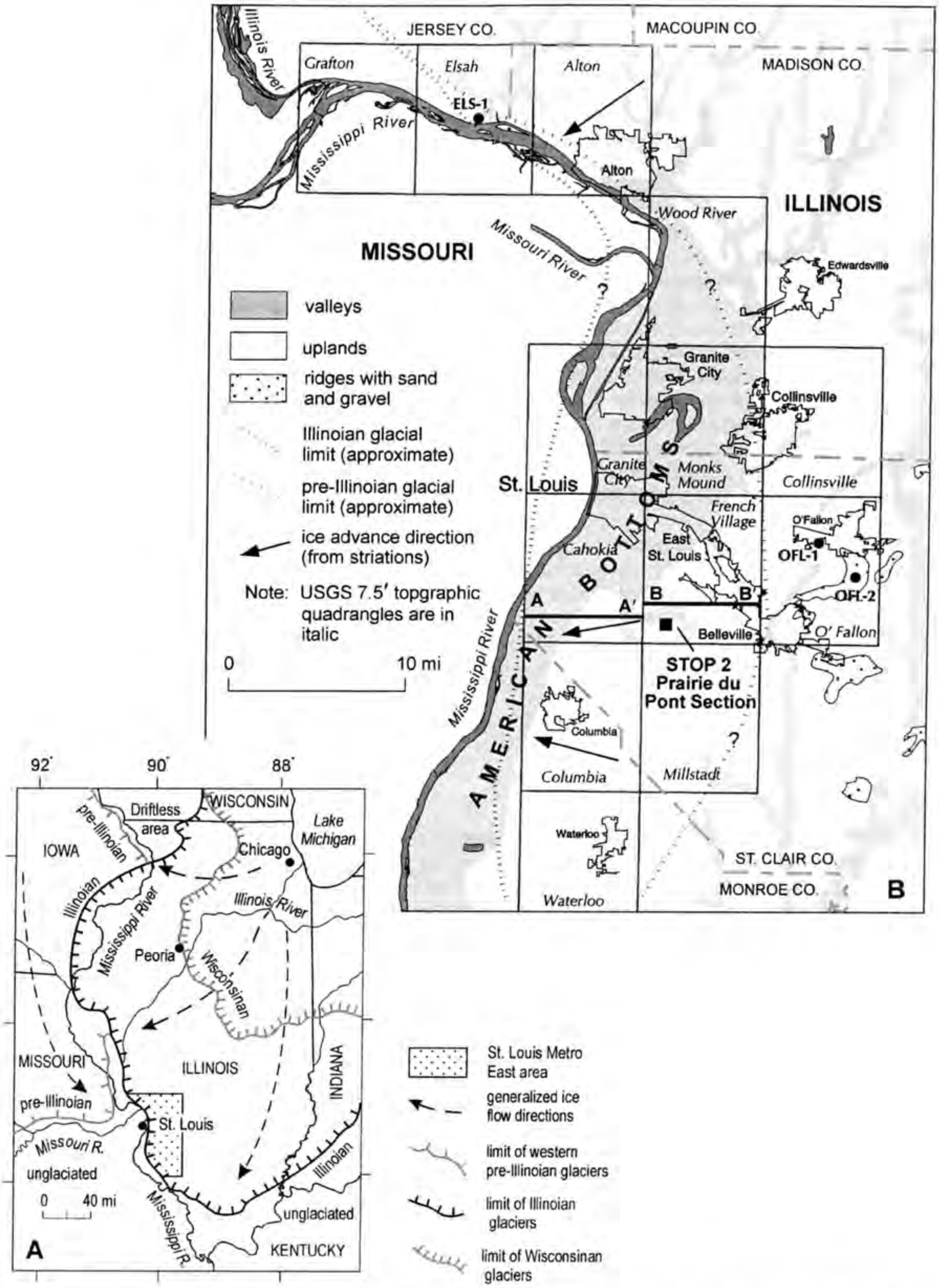

Figure 13 A. Location of the St. Louis Metro East area relative to ice margins of the major glaciations of the Quaternary. Subsurface ice margins are not shown. **B.** Regional map of the American Bottoms and nearby vicinity. Rectangular boxes show the areal outlines of 7.5-minute quadrangles that have been published or have been mapped for surficial and bedrock geology.

and pre-Illinoian deposits in the St. Louis Metro East area. In other thesis research projects, Bratton (1971) studied selected Wisconsinan deposits in Madison and St. Clair Counties and Odom (1958) mapped the bedrock and surficial geology in a portion of the Cahokia Quadrangle.

A series of 1:125,000 maps for societal planning in St. Clair County was published by Jacobs (1971). Ongoing mapping of surficial geology and bedrock is occurring in the entire St. Louis Metro East area (in Illinois) at a 1:24,000 scale (Fig. 13B). To date, surficial geology maps of the Grafton and Alton 7.5-minute Quadrangles (Grimley 1999a, b) are available. The stops on this field trip will be primarily in the Alton, French Village, Cahokia, Columbia, and Waterloo 7.5-minute Quadrangles, all of which have been or are currently being mapped.

Quaternary Deposits and Environments

The following discussion (organized from oldest to youngest units) is based on the literature as well as recent and ongoing geologic mapping in the St. Louis Metro East area:

Residuum

Silty clay loam to clay residuum (0 to 20 feet thick) is found lying on the bedrock in many areas. Particularly common in unglaciated areas or areas of thin till, the residuum is often thickest above limestone bedrock and is mainly weathered bedrock with some admixed loessal material. This type of material has been informally classified by Nelson et al. (1991) in southern Illinois (Pope County) as the Oak formation. Similar material in northwestern Illinois was interpreted to have been weathered mainly during the Tertiary and early Quaternary (Willman et al. 1989).

Pre-Yarmouthian Deposits

Till, alluvium, loess, and lacustrine sediments were common deposits of pre-Illinoian glaciers in southwestern Illinois. Pre-Illinoian deposits in the Metro East area are restricted to present-day upland areas, but are preserved mainly in buried valleys east of the Illinoian ice margin (e.g., Fig. 14B). The limit of pre-Illinoian glaciers, as noted by recent mapping, is interpreted as being similar to that delimited on a statewide scale by Willman and Frye (1970). Pre-Illinoian deposits in Illinois may be correlative with oxygen isotope stage 12, a period of substantial global ice volume about 450,000 years ago (Imbrie et al. 1984).

Pre-Illinoian till in this area, known as the Banner Formation (Willman and Frye 1970), has not been definitively found west of a curved line extending from Alton to Belleville to southeast of Waterloo (Fig. 13B). In the Alton and Elsah 7.5-minute Quadrangles, the Banner Formation is patchy and tends to be preserved mainly in bedrock lowlands or depressions (Grimley 1999b). Although nonexistent over much of the landscape, the Banner Formation, where present, can be thicker than younger Illinoian till deposits. In core OFL-1 of the O' Fallon Quadrangle (Fig. 13B), pre-Illinoian till is a silt loam diamicton up to about 30 feet thick that overlies lacustrine/loessal silts (Harkness Silt), which are locally preserved beneath the pre-Illinoian till. In unoxidized, calcareous till of core OFL-1, clay mineralogy averages 25% expandables, 41% illite, and 34% kaolinite plus chlorite in relative abundance. The comparatively high kaolinite-chlorite percentage and the shape of the X-ray diffraction traces suggest a great degree of local bedrock influence, perhaps by disintegration of shale into the clay fraction (H. D. Glass, ISGS, 1999, personal communication). Grain size distribution of till in this core (less than 2 mm fraction) averages 20% sand, 55% silt, and 25% clay, which is fairly typical for pre-Illinoian till in the region (McKay 1979).

Pre-Illinoian ice in the St. Louis Metro East area likely originated from the east or northeast, perhaps from an ancestral Huron-Erie Lobe (Willman and Frye 1970). Despite its proximity, a western source of glacial ice is unlikely because Calhoun County, Illinois, and western portions of St. Louis, Missouri, remained unglaciated (Fig. 13A). Scattered striations, found underneath probable pre-Illinoian till, indicate ice flow from the northeast to east-northeast direction (Grimley 1999b). The composition of the Banner Formation in this area mainly reflects the local substrate, including highly erodible Pennsylvanian bedrock, residuum, and proglacial silt, which were incorporated into the basal debris zone of glaciers. Low percentages of expandable clay minerals in unaltered till in core OFL-1 also suggest an eastern rather than a western source. Western-source pre-Illinoian tills in southeastern Iowa and western Illinois (Wolf Creek Formation) are known to have expandable clay mineral contents greater than 50% (Hallberg et al. 1980).

Fine-grained alluvium was also deposited and preserved in some areas, primarily to the west of the pre-Illinoian glacial limit, such as in the French Village Quadrangle (Grimley and McKay, unpublished map). Sand and gravel of pre-Illinoian age, as yet, have not been found in the Metro East area; perhaps these deposits were removed during stream incision of the succeeding Yarmouthian Stage.

Yarmouthian Deposits and Soil Development

Materials deposited during Yarmouthian time include alluvial and lacustrine silt, silty clay, and clay. These interglacial deposits, classified as the Lierle Clay Member of the Banner Formation (Willman and Frye 1970) are typically leached and altered by the strongly developed Yarmouth Geosol and can be up to about 20 feet thick in former depressional or alluvial areas (Fig. 14B). The Yarmouth Geosol developed during and subsequent to Lierle Clay deposition, yielding upwardly growing (cumulic) overthickened soil profiles.

The Yarmouthian Stage may have been of sufficient duration (about 240,000 years?) to have included several warm and cold Milankovitch cycles, perhaps oxygen isotope stages 7 through 11 (Grimley 1996). It is possible that ice advances may have occurred in the northern Great Lakes such that loess deposits may have accumulated in the Metro East area during parts of Yarmouthian time. The evidence for this is that the upper solum of the Yarmouth Geosol (developed in Lierle Clay) is typically overthickened and gradational with the overlying Illinoian silts. Overthickening and gradational contacts may have been the result of slow loess deposition.

Data from marine oxygen isotope stages 11 and 5 (probable warmest periods of the Yarmouthian and Sangamonian Stages, respectively) suggest a climate fairly similar to that of the Holocene (Droxler and Farrell 2000, Hodell et al. 2000). Although the older interglacial intervals may have been slightly warmer at times (Rousseau 1999), the most significant difference among the interglacials was more likely one of duration rather than climate.

Illinoian Deposits

Illinoian deposits are more widespread than the older Quaternary deposits. Almost all of the Metro East area was glaciated during the Illinoian Stage (Fig. 13), leaving behind an assortment of intercalated till, lacustrine, loessal, and outwash deposits. These deposits were likely laid down during oxygen isotope stage 6 (Curry and Pavich 1996, Curry and Baker 2000), between about 190,000 and 130,000 years ago. Regional indications are that glacial ice advanced from the Lake Michigan basin during the Illinoian Stage (Willman and Frye 1970) and spread almost completely across Illinois (Fig. 13A). Striations and hairpin erosion marks on the limestone bedrock at Lohr Quarry (northwest of Alton) confirm ice flow advance from the northeast to east-northeast direction in the Alton area (Grimley 1999b). In the Columbia and Dupo areas, striations on sandstone and limestone are aligned more east-west and are attributed to ice flow from the east (Fig. 13B).

Based on several new findings in outcrops and cores, early Illinoian loess and lacustrine sediment (Petersburg Silt) are more extensive than previously thought (Fig. 14B). Although occurrences of waterlaid and windblown silts beneath Illinoian till had been noted at such localities as Hickman Creek (Odom 1958), Powdermill Creek (McKay 1979), and a bluffside quarry near Alton (Willman and Frye 1958), the widespread occurrence of these deposits was not fully realized. The Petersburg Silt, predominantly of lacustrine origin, can be up to 60 feet thick in some buried valleys tributary to the Mississippi Valley (Fig. 14B). Much of the Petersburg Silt, which is generally crudely bedded and contains numerous *Picea* logs and fragments, was deposited by backwaters in tributary valleys to the Mississippi River Valley. Slow moving backwaters (slackwater lakes) originated as a result

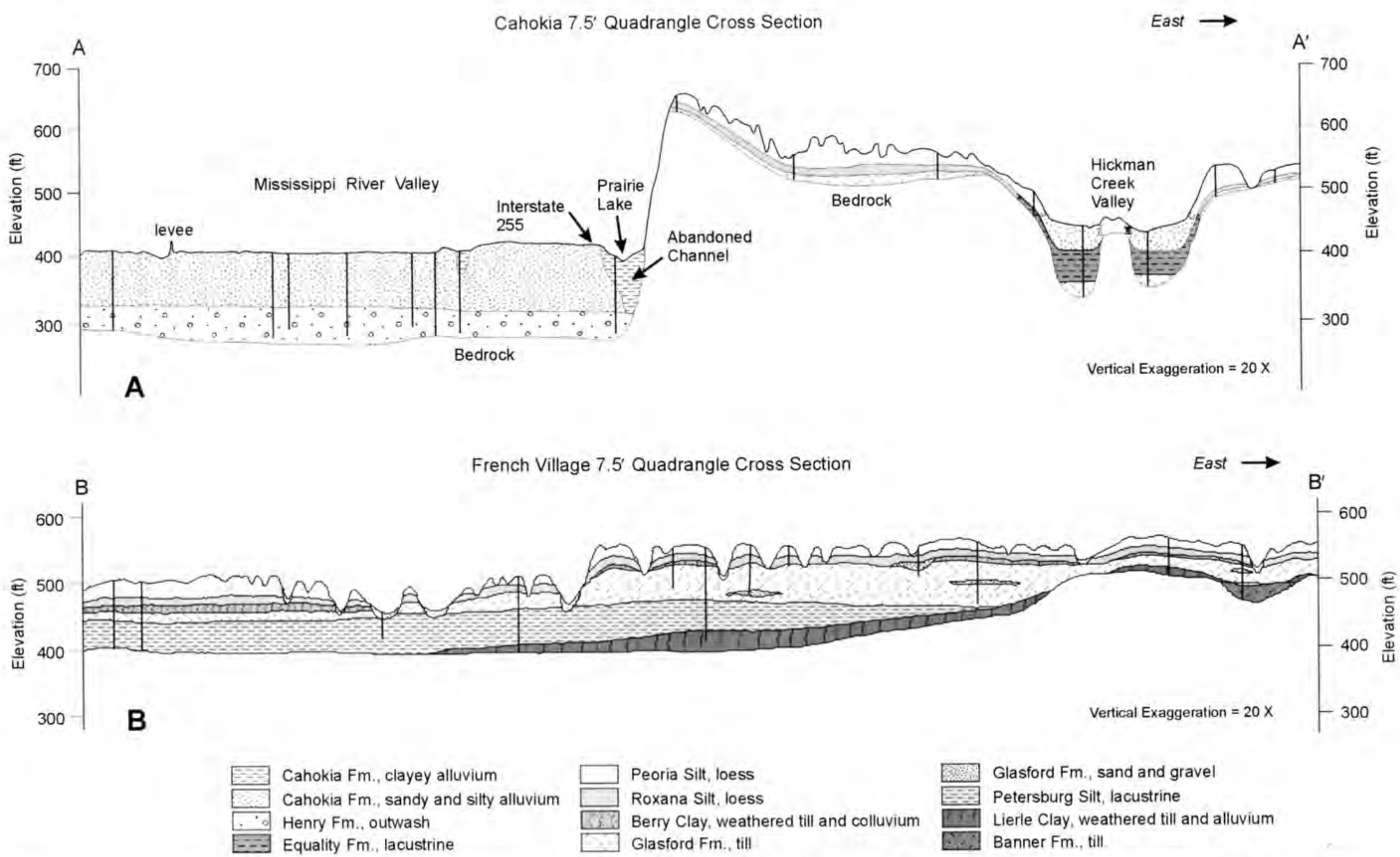

Figure 14 East-west cross-sections of Quaternary deposits across the **A.)** Cahokia 7.5-minute (A–A′) and **B.)** French Village 7.5-minute (B–B′) Quadrangles (see figure 13 for cross-section lines).

of rapid sedimentation and aggradation of the Mississippi River to a level above the tributary mouths. This aggradation likely occurred under the influence of glacial ice farther upstate in Illinois and in the Upper Mississippi River drainage area. At several localities, the Petersburg Silt contains primarily an aquatic gastropod fauna, which confirms a shallow water environment interpretation. Some terrestrial shells, wood fragments, and much loess were redeposited from upland areas into the shallow lakes. Climatic conditions were likely fully glacial, based on the fossil evidence, the presence of dropstones with Canadian shield lithologies, and the occurrence of Illinoian till immediately above the Petersburg Silt without an intervening paleosol. In some areas at higher elevations (generally above 480 feet), the Petersburg Silt is loessal in origin or is a mixture of loessal and lacustrine silt. Amino acid (alloisoleucene/isoleucine) epimerization ratios from gastropods in the Petersburg Silt are characteristically Illinoian, with values generally between 0.15 and 0.26 at the Powdermill Creek Section (Miller et al. 1994) and other sites in the Metro East area (Eric Oches, University of South Florida, 1999, personal communication).

An older silt deposit occurs discontinuously below the Petersburg Silt and above the Yarmouth Geosol. This unnamed leached silt (less than 5 feet thick) has only been observed in a few localities in Greene and Madison Counties (unpublished studies) but may be correlative to the Chinatown Silt of McKay (1979) at the Maryville Section. This silt was probably deposited during late Yarmouthian or very early Illinoian time. To avoid confusion, the Chinatown Silt name is not used here because the Chinatown Silt at the Powdermill Creek Section west of Belleville (McKay 1979, Miller et al. 1994) is now thought to be equivalent to the Petersburg Silt.

Illinoian till and ice marginal sediments (Glasford Formation) are common throughout the Metro East vicinity. The Glasford Formation diamicton ranges from loam to silt loam to silty clay loam. It is generally sandier to the northeast, clayier to the southwest, and siltier to the west. Thick residual clay soils on limestones in Monroe County probably contribute to a more clay-rich till in this area. Increasing silt content to the west is undoubtedly a result of incorporation of loess and lacustrine silt by ice movement in that direction, since involutions of silt are commonly seen in the field at the base of the Glasford till. Some laboratory data from the Glasford till indicate a silty basal zone with greater amounts of expandable clay minerals.

Sand-filled channels are occasionally found within the Glasford Formation. They occur primarily in the upper portion of the unit, but locally they are distributed throughout (Fig. 14B) or occur as R-channels at the base of the unit (we will likely see some of these sand bodies at the Prairie du Pont Section). Large ridges, containing sand and gravel and diamicton (all Hagarstown Member, Glasford Formation), occur in eastern Madison and St. Clair Counties. Based upon a boring near Shiloh (OFL-2; Fig. 13B), the loess-covered ridges are mainly composed of stratified sands (about 40 feet thick) that are intercalated with and underlain by diamicton (greater than 50 feet thick). The longest part of the ridge at Shiloh trends west-southwest, likely parallel to ice flow, based on a model for the formation of these ridges in Illinois (Jacobs and Lineback 1969). The formation of the Shiloh ridge may have been influenced by a bedrock low that occurs under the ridge; any explanation for its origin must be able to explain the inversion of topography. The Hagarstown "ridged-drift" may have formed as a result of enhanced deposition of mud flows and sands into a former low, in crevasses or in channels beneath the ice (Jacobs and Lineback 1969), or may be related to ice-contact debris from an ice lobe reentrant.

Terraces of sand and gravel (Pearl Formation), overlain by loess, occur along some valleys. Nonetheless, Pearl Formation sand and gravel (excluding the Hagarstown ridges) is less common than one would expect for an area near the margin of a major glaciation. Much of the outwash that was originally deposited must have been eroded during the succeeding interglacial (Sangamonian Stage) when large scale stream incision occurred.

Loess and lacustrine silt (Teneriffe Silt) blanketed both Glasford Formation and Pearl Formation deposits following ice retreat to the northeast. These late-Illinoian silts are normally 3 to 10 feet thick and are typically a yellow-brown to gray silt loam to silty clay loam with relatively scarce sand and pebbles. These silts were commonly the parent material for the Sangamon Geosol and so are typically weathered throughout their thickness.

Sangamonian Deposits and Soil Development

The last interglacial warm period (known as the Sangamonian Stage), although of considerable duration (Curry and Baker 2000), largely resulted in a record of soil formation (Sangamon Geosol) rather than extensive deposits. The Sangamonian interglacial age lasted about 75,000 years (Curry and Baker 2000), which was not nearly as long as the Yarmouthian interglacial, based on physical, mineralogical, and elemental indicators of soil development (Willman and Frye 1970, Grimley 1996). The soil solum of the Sangamon Geosol is generally not as thick as the Yarmouth Geosol solum, yet is thicker than that of the modern soil. However, whereas the Yarmouth Geosol has often been stripped or truncated by succeeding Illinoian glacial erosion, the Sangamon Geosol is often well preserved because of non-erosive burial by a blanket of Wisconsinan loess.

Where present, Sangamonian deposits are mainly alluvial, lacustrine, or accretionary. Primarily silty clay loam to silty clay deposits, with sparse pebbles, these deposits have been referred to as the Berry Clay Member of the Glasford Formation (Willman and Frye 1970). The Berry Clay, generally less than 10 feet thick, is mainly found in areas that were formerly flat-lying or depressional areas on the landscape where slopewash was deposited and shallow lakes may have remained during the interglacial. Because the Berry Clay and Teneriffe Silt were both altered by later Sangamonian weathering, they are commonly difficult to differentiate.

Based on ostracode and pollen studies in south-central Illinois, climatic conditions during the Sangamonian Stage were probably fairly similar to those of today, except that winters may have been slightly warmer during portions of Sangamonian time (Curry and Baker 2000).

Wisconsinan Deposits

Although glacial ice did not reach southwestern Illinois during the last glaciation, loess, outwash, dunes, and lake sediment resulted from glaciation in the Upper Mississippi River drainage basin. Glacial ice in Illinois advanced to within about 80 miles of the St. Louis Metro East area; however, most of the outwash in the American Bottoms and related loess deposits were probably from Upper Mississippi and Missouri Valley sources, according to mineralogical compositions (Glass et al. 1968, Grimley 2000).

Outwash sand and gravel (Henry Formation) is up to 50 feet thick in the deepest portions of the American Bottoms (Bergstrom and Walker 1956, Grimley and McKay, unpublished map), overlying bedrock (Fig. 14A). The Henry Formation was deposited in a braided channel system as the river aggraded in response to glaciation in the Upper Midwest. At two or three operating pits in the American Bottoms, coarse sand with some gravel is currently being dredged, mainly for construction use, from a depth of about 60 to 100 feet. Illinoian and pre-Illinoian outwash may exist in the American Bottoms, but these deposits would be extremely difficult to distinguish from younger outwash. The available evidence suggests that much of the older outwash was scoured away. In addition to being a local material resource, the Henry Formation is also a significant groundwater resource (Bergstrom and Walker 1956). However, in recent years, extensive contamination of this aquifer has been a significant problem (Rehfeldt 1992).

Loess deposits, deflated from the huge expanse of floodplain in the American Bottoms, are up to 100 feet thick on some upland bluffs near Collinsville but thin exponentially to about 20 feet thick towards the eastern portion of the Metro East area (Fig. 14; McKay 1977). Loess deposits are somewhat thinner, ranging from 15 to 40 feet thick, near Alton (Grimley 1999b) and Columbia because a steep bedrock bluff may have restricted loess deflation from the valley. Additionally, valley orientation is parallel to the prevailing westerly winds near Alton and a more narrow valley exists near Columbia. Wisconsinan loess deposits have been classified as two major formations, Peoria Silt and Roxana Silt (Willman and Frye 1970). The older Roxana Silt, a pinkish-brown to pinkish-gray silt loam, was deposited between about 28,000 years ago and 55,000 years ago (McKay 1977, 1979, Hansel and Johnson 1996). The Peoria Silt, the younger and normally thicker unit (Fig. 14), is a yellow-brown to gray silt loam that was deposited between about 25,000 years ago and 12,000 years ago (McKay 1977, 1979, Hansel and Johnson 1996, Grimley et al. 1998). Loess deposits are thick enough in the more northern Metro East areas (near Collinsville) that the eastern bluffs bordering the American Bottoms are composed entirely of loess, with till and bedrock lying at depths below the level of the present floodplain. On upland areas, loess deposits generally blanket the landscape due to their deposition by atmospheric settling. Yet, loess deposits have commonly been eroded along steep ravines and valleys, thus exposing the underlying till, lake deposits, residuum, or bedrock.

Lacustrine deposits are fairly commonly preserved in terraces of tributary creeks to the Mississippi Valley. Fine sands, silts, and silty clays (Equality Formation) have been noted in tributary valleys, such as those of Piasa Creek (Elsah 7.5-minute Quadrangle, unpublished) and Hickman Creek (Fig. 14A; Cahokia 7.5-minute Quadrangle, unpublished) within a couple of miles of their outlet to the Mississippi Valley. Lake sediment was likely deposited by backwaters of the Mississippi-Missouri Rivers that inundated tributary valleys, forming slackwater lakes during Mississippi River aggradation when outwash and loess were also being deposited. The environment and level of deposition of the Equality Formation were similar to that described for the Illinoian Petersburg Silt. Postglacial downcutting through the lake sediments has left behind terraces in some areas. Terraces, capped by a few feet of loess and underlain by as much as 105 feet of slackwater sediment, are common at about the 470- to 480-foot elevation. These terraces probably are correlative to the Cuivre Level of the St. Charles Terrace Group in Missouri (Hajic et al. 1991). On Piasa Creek terrace core ELS-1, AMS radiocarbon ages of 29,600 ± 700 years B.P. (before present) (A-0011; shells), 42,000 ± 3100 years B.P. (A-0010; shells), and 43,772 ± 1590 years B.P. (A-0022; seeds) were determined from samples of pinkish-brown silty clay at depths of 66 feet, 105 feet, and 107 feet, respectively. The similarity in age and color of this lower Equality Formation to that of the Roxana Silt is attributed to synchronous deposition. Gastropods (e.g., *Gyralus, Amnicola,* and *Valvata tricarinata*), small bivalve shells, and ostracodes (*Candona caudata, Candona rawsoni,* and *Limnocythere herricki*) in the lower Equality Formation are typical of slow moving water. The ostracode assemblage (identified by B. B. Curry, ISGS) and plant macrofossils (amaranths and chenopods; identified by R. G. Baker, University of Iowa) are indicative of a cool climate that was as dry or drier than today, such as that in the northern Great Plains.

Holocene Deposits and Modern Soil Development

Deposits of the current interglacial period (the Holocene) include alluvial fans, point-bar deposits, and abandoned meander fills in the American Bottoms as well as upland stream alluvium (Fig. 14). All of these deposits are classified in the Cahokia Formation (Willman and Frye 1970). Most small upland streams contain silty alluvium because of the large amount of incision and slumping in thick silty loess deposits that are easily erodible by water. Some of the larger river tributaries to the Mississippi River contain more sandy alluvium. In lower reaches of the larger upland tributaries, the Cahokia Formation commonly overlies Equality Formation lake deposits (Fig. 14A).

In the American Bottoms, the Cahokia Formation consists of thick (up to 60 feet), well-sorted sandy deposits of former point bars and thick (up to 60 feet) silty clay fills in abandoned river channels and oxbow lakes (Fig. 14A; White et al. 1984, Smith and Smith 1984). These units overlie Henry Formation sand and gravel (Fig. 14A). Characteristics of surficial deposits in the American Bottoms are somewhat predictable based on the geomorphology (Yarborough 1974, Hajic 1993), data from USDA soil survey maps (Goddard and Sabata 1982, Wallace 1978), and remote sensing data.

On stable landscapes, modern (Holocene) soil profiles have developed in the Peoria Silt on upland areas and in the Cahokia alluvium in the valleys and bottoms. Because of their younger substrate, modern soils developed in the Cahokia alluvium are much less developed (lacking a B horizon or having only a weak B horizon) than those developed into Peoria Silt on stable uplands. Of course, soils in steeply sloping areas have weaker development because of erosional processes and may contain thin layers (as much as 10 feet) of colluvium.

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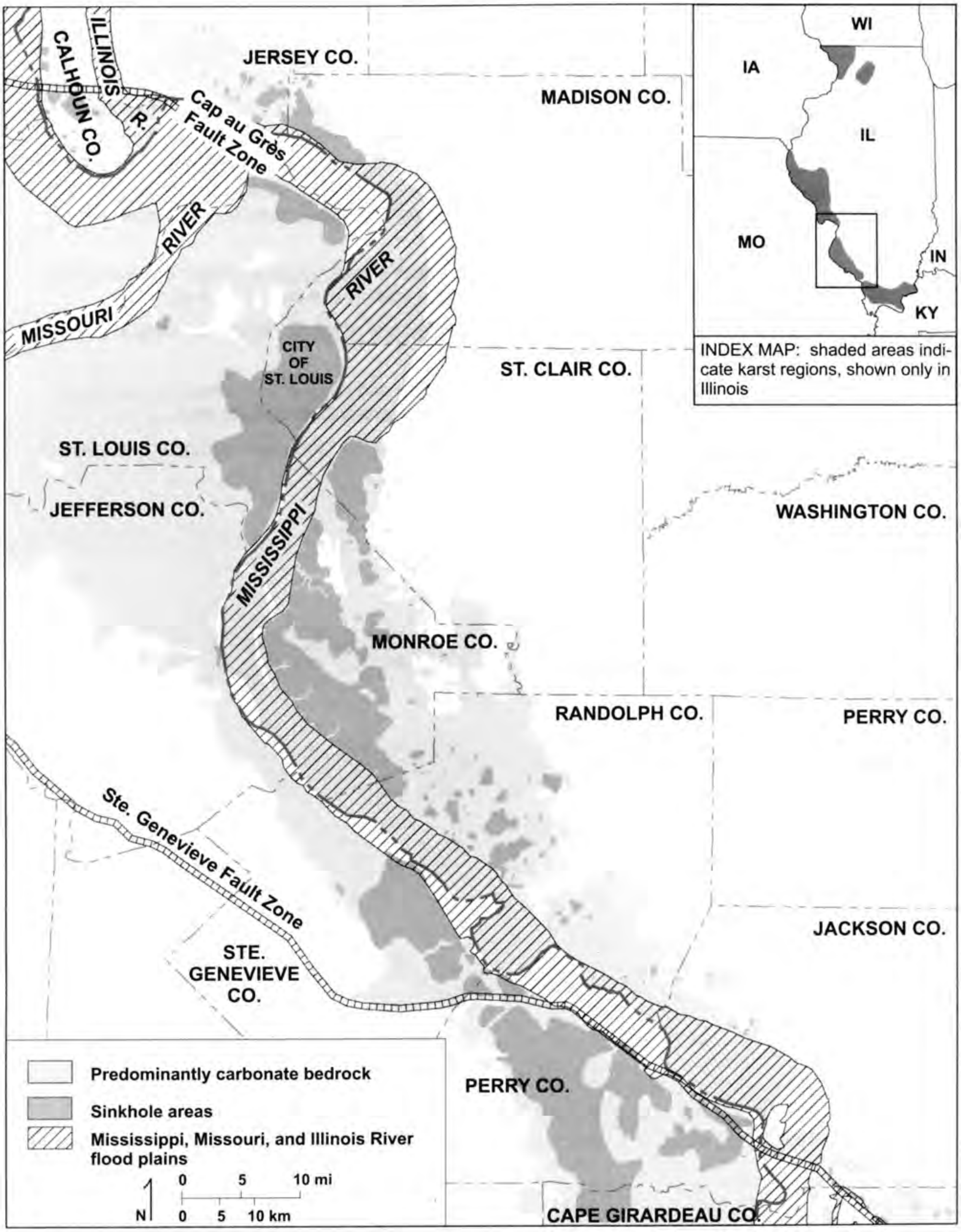

Figure 15 Map showing the extent of carbonate-dominated bedrock, sinkhole areas, major structural features, and major floodplains of southwestern Illinois and southeastern Missouri. The inset index map shows the five karst regions of Illinois.

Karst of Southwestern Illinois

C. Pius Weibel

Karst is defined by Ford and Williams (1989) as " . . . terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well-developed secondary porosity." Caves, conduits, numerous and large springs, swallow holes, sinkhole drainage, and rapid aquifer recharge/discharge are features that typify the distinctive hydrology of karst. Fluted outcrops, sinkholes (closed depressions), blind valleys, cave openings, karst windows, and deranged drainages are features that typify karst terrain. In Illinois, karst occurs primarily in carbonate rock, particularly limestone, although karstic dissolution features have been observed in quartzose sandstone (Weibel 1999). About 25% of the bedrock surface of Illinois is composed of carbonate rock, and about 9% of the state is included in the five regions that contain evidence of numerous karstic features at the land surface (Weibel and Panno 1997; see index map, Fig. 15).

The sinkhole plains of southwestern Illinois along with those of southeastern Missouri form a broad belt that straddles the state boundary and Mississippi River (Fig. 15). As in most karst terrains of the world, residents live in a landscape that is unique and beautiful, but also rife with the problems associated with sinkholes and poor groundwater quality.

The karst terraine of southwestern Illinois occurs primarily on Mississippian carbonate bedrock and is bounded to the west by the Mississippi River and its floodplain (Fig. 15). The terrain generally has developed on the uplands that rise 60 to 100 meters (200 to 350 feet) on the east side of the broad valley. Pleistocene glacial deposits are thin or absent in the area, although thick deposits of loess are present. In Illinois, karst landscapes formed where Mississippian carbonate (mostly limestone) bedrock subcrops beneath the Pleistocene. Across the Mississippi River in Missouri, karst landscapes formed on Ordovician and Mississippian carbonate bedrock. In the southern part of the area, the Ste. Genevieve Fault Zone traverses the karst terrain (Fig. 15) and separates Mississippian carbonates to the northeast from Ordovician carbonates to the southwest. North of the City of St. Louis, the terrain continues to Alton, Illinois, and to the Lincoln Hills (between the Mississippi and Illinois Rivers) where it crosses the Cap au Grès Faulted Flexure (Fig. 15). Karst features are very common throughout this area of Illinois, particularly in west-central St. Clair County and western Monroe County.

Much of the karst of the St. Clair-Monroe-Randolph County area is known as *mantled karst*, which is defined as karst covered with allochthonous sediments where the karst is part of the modern landscape and pre-existed prior to being covered (White 1988). In this region, the allochthonous sediments consist of drift and loess.

Carbonate rocks generally have low primary porosity and permeability; however, secondary porosity (fractures) permits the rapid transport of large volumes of water into and through the rock. The movement of surface waters (rainwater and snowmelt) through the soil and into fractures in this soluble limestone bedrock caused the development of karst in this area. Water infiltrates the soil and dissolves carbon dioxide, creating carbonic acid. Most of the carbon dioxide is generated by bacterial microbes within the soil; a small amount is from the atmosphere. The slightly acidic water infiltrates fractures, joints, and bedding planes in the limestone bedrock beneath the soil. Small amounts of calcite are dissolved by carbonic acid in accordance with this simplified reaction: $CaCO_3 + H^+ \_ Ca^{2+} + HCO_3^-$, until the water approaches saturation with respect to the equilibrium solubility of calcite (White 1988). The slow dissolution of limestone over thousands to hundreds of thousands of years gradually enlarges joints, fractures, and pathways along bedding planes through which water moves. Some pathways become large conduits or caverns through which groundwater flows to points of discharge (e.g., springs).

In addition to the presence of soluble limestone bedrock, several other factors contribute to the occurrence of karst. The elevated upland along the Mississippi River valley provides the hydraulic head for water to percolate downward to the level of the Mississippi River. Where the bluffs are steep, sinkholes are abundant on the bluff, and springs are numerous near the base of the bluff.

In northernmost Monroe County and near the village of Columbia (see index map), the steep bluff is absent and a gap occurs between the sinkhole areas of St. Clair and Monroe Counties (Fig. 15). This gap is underlain by the Columbia Syncline (see Fig. 11), which contains a Pennsylvanian outlier dominated by shale. Sinkholes are virtually absent within this area, except near the edge of the outlier, because the less permeable Pennsylvanian bedrock inhibits karst formation in the underlying Mississippian carbonate rocks.

Sinkholes, also known as dolines, are topographic depressions that are considered to be index landforms of karst (Ford and Williams 1989). These circular to subcircular features form as the continued dissolution of bedrock enlarges crevices and cavities in the bedrock below the soil cover (and drift, if present). As a crevice enlarges, the soil cover begins to collapse into the crevice, creating a soil arch, and the sediment is transported away by water flushing through the underground karst drainage system. The soil collapse continues to propagate upward until the surface is breached and a hole is formed. Erosion by water flowing into the hole reshapes the hole into a funnel-shaped depression. As cavities within the bedrock enlarge, the roof may collapse, and both bedrock and the soil cover will drop into the cavity, creating a new sinkhole. The speed at which sinkholes form is unpredictable; dissolution of the bedrock is a very slow process whereas soil arch failure can be catastrophically rapid (White 1988).

Sinkholes are abundant in the karst terrains of southwestern Illinois and across the Mississippi River in Missouri. In Illinois these sinkholes typically are nearly circular in plan view and range from less than 1 meter (3.3 feet) with a single drain into the bedrock, to nearly 1 kilometer (0.62 mile) in diameter with multiple drains. The largest sinkhole clusters (by area) and densest concentrations occur where the bedrock is the middle Mississippian limestone sequence composed of the Salem, St. Louis, and Ste. Genevieve Limestones (see cover for example). Sinkhole densities are as great as 230 sinkholes per section (approximately equal to 1 square mile or 2.6 square kilometers) (Panno 1996).

Sinkholes act as natural drains for rainfall and snow melt, concentrating large volumes of water that flow rapidly into the underlying bedrock. Most groundwater in karst aquifers of this area ultimately flows through fissures and conduits that range in size from about 1 centimeter (0.03 feet) wide to more than 5 meters (16 feet) in diameter. Fissures and conduits constitute a large percentage of the karst aquifer (Quinlan 1988). As dissolution enlarges joints at the bedrock surface, bedding plane partings are also enlarged to form horizontal conduits and caves. These conduits and caves provide lateral routes for movement of the infiltrating water toward discharge springs. In many respects, the karst "plumbing" of sinkholes, conduits, caves, and springs is similar to manmade storm sewer systems.

Karst aquifers, which are locally important aquifers, are very susceptible to surface-derived contamination. In most areas, the recharge to karst aquifers is generally rapid (analogous to water movement to drainage tiles) and carries materials from the land surface that may include human and animal wastes, pesticides, fertilizers, urban runoff, and other waste products associated with humans. Unfortunately, residents who pump groundwater for domestic use from karst aquifers risk ingesting these contaminants. Rare and endangered species that inhabit underlying caves are also at risk from chemical and bacterial contamination in groundwater. In contrast, the recharge to non-karst aquifers typically undergoes a slow migration through materials (e.g., thick, clay-rich glacial diamicton) that generally provide sufficient time and the proper environment for chemical, biological, and physical degradation and retardation of pollutants.

Many sinkholes, unfortunately, have been utilized as disposal sites for all types of refuse. Contaminants from the refuse often move down the sinkhole and eventually pollute the groundwater. A greater source of pollution probably is the result of the rapid increase in residential development in the Monroe and St. Clair Counties within the last 15 years and the consequential rapid increase in the number of private septic systems. Many septic systems in southwestern Illinois commonly drain directly into sinkholes and consequently introduce septic effluent into the groundwater. Panno et al. (1997a, b) demonstrated that drainage from most of the private septic systems in Illinois' sinkhole plain exceeded state and local health codes for fecal coliform content. At least partly

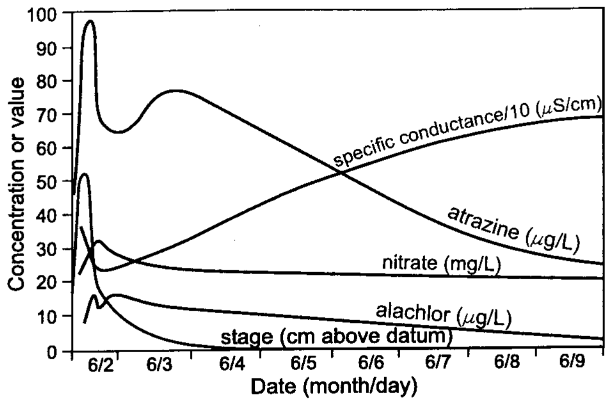

Figure 16 Graph showing discharge and other parameters from Kelly Spring, Monroe County, Illinois, during a 2.7-centimeter (1.05-inch) rainfall event in the spring of 1994. Stage level indicates discharge rate from the spring, showing a characteristic storm pulse. Specific conductance of the water decreased rapidly because of the dilution of the sudden recharge of rainwater. Agricultural concentrations increased rapidly to peak values just after the discharge peaked, probably because they were briefly attenuated by the soil immediately after application. Modified after Panno et al. (1995).

because of this practice of septic system construction, 55% of wells sampled in Monroe County (in July 1995) tested positive for coliform bacteria (Panno et al. 1996).

Although sinkholes act as funnels for water to recharge karst aquifers, springs are points of discharge at the distal ends of groundwater basins. Most of the world's largest springs are karst springs, rivaled only by those from volcanic rocks (Ford and Williams 1989). Karst springs typically discharge with a characteristic pronounced storm pulse (Fig. 16). Generally there is a short lag between the onset of a precipitation event and the rise in the discharge rate from a spring. During this lag time, water levels rise in the headwater areas of the groundwater basin and the hydraulic head increases. The pulse of water moves rapidly through the basin and causes discharge at the spring to increase. This increase from base flow to a rate many times greater is often abrupt. After the discharge reaches its peak, the flow decreases at a slower rate than the increase rate.

Most of the springs in southwestern Illinois (and probably southeastern Missouri) are contaminated with bacteria derived from a variety of sources, including agricultural activities (fertilizers, pesticides, and livestock), effluent from private septic systems, and natural sources (Panno et al. 1996). Contaminants from the land surface that are transported into shallow karst aquifers may include relatively high concentrations of nitrate, bacteria, and organic chemicals (Fig. 16).

Caves are a common feature in karst terrains and often are the most well-known of the many dissolution features. Conduits are the passages in the bedrock through which water flows in the underground drainage system, and caves are an arbitrarily defined subclass of the larger conduits. White (1988) probably best defined a cave as "a natural opening in the earth, large enough to admit a human being, which some human beings choose to call a cave." Other cave definitions require certain minimal lengths, biological characteristics, or other conditions, such as total darkness. Caves can form in limestone, dolomite, gypsum, and other soluble bedrock in areas where there is sufficient precipitation, in the form of rain or snow melt, so that the karst aquifers are being regularly recharged. The recharging process ensures that undersaturated water (with respect to calcite or other minerals) is in contact with the soluble rock and that water movement removes the dissolved bedrock. Most cave passages developed from small conduits that were controlled by pre-existing bedding features (beds or bedding plane features) or by prominent joints and fractures (Palmer 1991).

The longest caves in Illinois occur in Monroe and St. Clair Counties; there are more than 90 cave openings in Monroe County alone. In Perry County, Missouri, the Ordovician Joachim Dolomite (Whiterockian Series) and Plattin Formation (Mohawkian Series) underlie extensive sinkhole plains and are host to hundreds of caves, including several of the longest caves in Missouri and the United States (Panno et al. 1999).

Caves are generally the main conduits of underground drainage systems or groundwater basins. Groundwater drainage systems can be divided into discrete groundwater basins analogous to watersheds; each groundwater basin comprises a conduit system that drains a specific recharge area. The distal end of a groundwater basin generally is characterized by one or more springs that either discharge into a surface stream or form the headwaters of a surface stream. The karst of southwestern Illinois and the adjacent karst of southeastern Missouri include numerous groundwater basins that discharge ultimately to the Mississippi River. Panno et al. (1999) defined the groundwater basins of several cave systems in Monroe and St. Clair Counties and concluded that local structural geology has a strong influence on the basin boundaries and groundwater flow direction within each basin.

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Silurian Geology and the History of the Stone Industry at Grafton, Illinois

Donald G. Mikulic and Joanne Kluessendorf

This chapter of the guidebook concentrates on the Silurian geology in this area and underscores the importance of the Grafton stone-quarrying industry to regional history and economic development.

The old quarries at Grafton represent one of the most important geologic sites along the Mississippi River in Illinois. During the nineteenth century, Silurian rocks here formed the basis of the largest building-stone industry in the region, supplying most of the dimension stone used in the St. Louis area. This site also has been one of the best-known fossil-collecting localities in the Midwest, and thousands of specimens of the trilobite *Gravicalymene celebra* have been collected here over the last 150 years. The Grafton quarries have also been the destination of many field trips, including the Fourth Tri-State Field Conference in 1936. The following paragraphs provide a brief history of Grafton's settlement and its stone industry, including a discussion of the Silurian geology and paleontology of the area.

Settlement of Grafton

Grafton is one of the oldest communities in this part of Illinois—and one whose destiny has been controlled by geology. At the beginning of the nineteenth century, Grafton's location at the junction of the Illinois and Mississippi Rivers probably was considered one of the most promising settlement spots along a burgeoning water-transportation network. With roads almost nonexistent at the time, rivers offered the only way to move materials and people for great distances. In particular, the Illinois River was becoming a major transportation route, connecting the rapidly developing regions of northern Illinois with St. Louis, then the most important city in the West. Discussion of constructing a canal to connect Lake Michigan with the Mississippi River at the time certainly suggested that Grafton would eventually become a prime location along one of the most important transportation networks in the nation (Mikulic and Kluessendorf 1999a).

In addition to its location at the confluence of two major rivers, Grafton possessed the right combination of features for a river port. Other sites in the area were handicapped by one of two undesirable geologically controlled features, making them unsuitable for development. To the west and north, the Illinois River flows through a low-lying floodplain that is regularly inundated by floodwaters. The same situation exists to the south where the Mississippi River is also bordered by a broad floodplain. To the east, steep, high bluffs extended to the banks of the Mississippi River, affording little space on which to build. In contrast, Grafton was located at one of the few places in the area where the bluffs are located far enough back from the riverbank to provide space for a community to develop, but offer some high ground close to the bank. More importantly, the concentration and size of the "hollows" that dissect the river bluffs at Grafton provided more high ground on which to build compared to other locations. Confined to a limited area between the river bluff on the north and riverbank on the south, Grafton developed into a linear-shaped community. Unfortunately, the "high ground" at Grafton has not been high enough to avoid all large floods, and every few decades much of the community is underwater. While the location of Grafton was ideal for river transportation, the surrounding high, steep riverbank bluffs made it very difficult to construct roads to any of the nearby communities. As a result, Grafton was a relatively isolated river town throughout most of the nineteenth century.

Grafton Stone Industry

Grafton possessed another geological feature that was to play a major role in its development. The steep limestone and dolomite bluffs lining the Illinois and Mississippi Rivers were an obvious source of the lime and building stone needed by pioneer settlers. In the early 1800s, it was discovered that the bluffs at Alton were composed of limestone that made a high-quality lime when burned. More importantly, however, a small area around Grafton was found to contain beds of dolomite that produced excellent building stone—a much rarer commodity. This stone was composed of thick, well-bedded layers that were easily quarried. In addition, this stone cropped out all over town, making it readily available to anyone needing stone to erect a home or business.

Exactly when and by whom quarrying was begun at Grafton has not been recorded, although 1836 is a commonly given date. The first stone-quarrying was likely not undertaken for commercial reasons, but rather by individuals to obtain stone for their own building needs. Several buildings constructed in the 1830s and 1840s, representing this period, still survive in Grafton. Quarries at Grafton were mentioned in 1848 by the German Henry Lewis in his travels along the Mississippi River, indicating their early importance to the community. Furthermore, the 1850 federal census lists four stone masons in Grafton, which would have been a large number for such a small community, so it is probable that some stone was being dressed for use in other markets.

The 1850s mark the true beginning of the Grafton stone industry. At that time, Silas Farrington of Grafton and John Loler of St. Louis founded the Grafton Stone Works, which was established to quarry and ship building stone to the lucrative St. Louis market (Hamilton 1919). Throughout the late nineteenth century, this stone industry was the major business enterprise in Grafton. Hundreds of workers labored in the quarries to produce high-quality building stone, as well as riprap for river-bank improvements. Very little of the stone was actually used in Grafton, however, and the main sales offices for this and most later companies were located in St. Louis. Throughout the late 1800s, most of the major St. Louis building projects utilized Grafton building stone, in some cases for facing, but, more typically, for load-bearing foundations. Prominent examples of construction using Grafton stone are the Eads Bridge, the first bridge across the Mississippi in the area, and the Lindell Hotel, at one time the largest hotel in the nation. By 1900, with the advent of poured concrete and internal steel supports in large buildings, the need for foundation stone had largely disappeared. After that, the Grafton stone industry continued to supply riprap for river bank construction and, to a lesser extent, for building stone and crushed stone. The last quarry at Grafton closed in 1975.

A number of stone buildings and structures in Grafton have been placed on the National Register of Historic Places (see Stop 7 for details), particularly those in the Grafton Historic District, which runs along Main Street west from Jerseyville Hollow Road (Anonymous 1994). Unfortunately, some of the most historically important stone structures, such as the Grafton Stone & Transportation Company quarry office, have not been listed on the Register. Comparing these stone buildings with one another reveals a wide range of stone quality and masonry styles that are related both to the period of construction and to the cost of the stone materials.

Silurian Geology in the Grafton Area

Silurian rocks are poorly exposed in most of this region of the Midwest; however, they crop out extensively in scenic and scientifically important river bluffs in and around Grafton. The outcrops begin at Rice Hollow and continue west through Grafton, Pere Marquette State Park, and on into Calhoun County and adjacent areas of Illinois and Missouri. At Grafton, Silurian dolomite forms most of the lower portion of the high cliffs, and many of the local hollows contain scenic bluffs and small waterfalls associated with these rocks. Silurian strata in the area have a slight dip towards the east. As a result, the youngest strata are exposed only around Grafton, and the Silurian becomes progressively thinner with only older beds exposed to the west.

Despite their economic and scientific importance, the Silurian rocks and fossils at Grafton have received surprisingly little scientific study and have remained poorly understood. Stratigraphically, these rocks generally have been referred to as Niagaran, beginning with their earliest description by Hall (1858), Worthen (1868), and McAdams (1885). In 1926, Savage divided the Silurian here into several formations, but little detailed work has been done since. Recently, Anthony Butcher, a student at the University of Portsmouth (United Kingdom), has undertaken a comprehensive study of the biostratigraphy and sedimentology of the Silurian here, which should greatly improve our understanding of these rocks.

The lack of previous work was not due to a lack of exposures, especially when the quarries were operating. In fact, the entire Silurian section, as well as both the Ordovician/Silurian and Silurian/ Devonian boundaries, are well exhibited in a series of quarries and outcrops throughout the area. In this paper, we have subdivided the Silurian rocks into five, mostly informal, units (Fig. 17), pending further work.

The basal Silurian unit (unit A) is the Bowling Green Dolomite (as defined in Missouri by Thompson and Satterfield 1975), which was formerly referred to as the Edgewood Formation. In Missouri, this unit is assigned to the early Llandovery based on conodonts (Thompson and Satterfield 1975, McCracken and Barnes 1982). (In this paper, we have not distinguished strata at the base of the Silurian equivalent to the Bryant Knob Formation that underlies the Bowling Green in Missouri.) Generally, unit A, which is 29 feet (9.5 meters) thick, is a very finely to finely crystalline, massive to thick-bedded, burrow-mottled, very light yellowish-gray dolomite, that weathers to a conspicuous yellowish-orange color. This unit contains moderately common, very fine to fine bioclasts that indicate a diverse marine fauna, including brachiopods, rugosid corals, trilobites, gastropods, cornulitids and fine pelmatozoan debris. The bioclasts are typically biomoldic and occur in wackestone to packstone textures with some grainstones locally; in places, the bioclasts are chertified. Reworked ooids and a skeletal lag occur at its base. The brachiopod *Platymerella* is found locally at the top of this unit. Scattered chert nodules also occur near the top. The Bowling Green is dominantly a well-bioturbated, subtidal deposit with a transgressive lag at its base. The top of unit A is very irregular, possibly brecciated, and exhibits *Thalassinoides* burrows filled with light greenish-gray argillaceous material. This contact may be equivalent to the contact between the Drummond and Offerman Members of the Kankakee Dolomite in northeastern Illinois, marking the sequence boundary between the Rhuddanian and Aeronian Stages of the Llandovery. The Ordovician-Silurian boundary is best exposed in the Grafton area at an old quarry and natural outcrops at Camden Hollow, on the eastern edge of Pere Marquette State Park. Underlying the Bowling Green is the Noix Oolite, which had been considered Silurian in age and part of the Edgewood Formation (Willman and Atherton 1975) but is now known to be late Ordovician (Thompson and Satterfield 1975, McCracken and Barnes 1982). This 1.5-foot-thick (0.5 meter) unit is a light gray, oolitic to bioclastic dolomite (dominantly moldic), containing rip-up clasts of underlying greenish-gray Maquoketa Shale and small phosphatic pebbles at its base. The top of the Noix, which marks a major sequence boundary, displays several inches of relief and may be topped by a mineralized crust. The Noix is also found in adjacent Daggett Hollow, but is absent farther east.

The overlying unit B is a middle to late Llandovery unit equivalent to the Kankakee Dolomite in northeastern Illinois and the Sexton Creek Limestone in southern Illinois and Missouri and has been referred to these formations by previous authors. The age assignment is based on the occurrence of the brachiopod *Platymerella* at the top of the underlying Bowling Green and the presence of *Stricklandia protriplesiana* (Amsden 1974) at the top of this unit. Unit B, which is 15 feet (5 meters) thick, is massive to irregularly medium-bedded. It generally contains numerous, very thin (less than 1 foot) cycles composed of porous, light gray (weathers yellowish-orange), coarsely crystalline dolomite (bioclastic wackestone to grainstone) grading up into dense, nonporous, brownish-gray, finely crystalline dolomite. Each cycle is topped by an irregular, mineralized (typically glauconitic) surface. These surfaces commonly are marked by burrows, including *Thalassinoides,* some of which may be exhumed. *Chondrites* burrows are present locally within the cycles. The upper foot or so of unit B contains larger bioclasts, including *Stricklandia* brachiopods, and *Thalassinoides* burrows filled with argillaceous material. Unit B was deposited in a subtidal environment; the numerous thin cycles may be tempestites, indicating deposition above storm wavebase. The numerous glauconitic surfaces, or hardgrounds, mark episodes of non-deposition. The setting may have been dysaerobic at times, as suggested by the presence of *Chondrites* zones. The tops of the cycles, however, probably represent oxygenated conditions based on the presence of *Thalassinoides* burrows. Overall, unit B represents a shallowing-upward sequence, with the uppermost few feet marked by a more diverse, normal-marine biota. The upper surface is mineralized. This upper interval is typically very porous and vuggy, possibly the result of carbonate dissolution during karstification. This horizon marks a major sequence boundary between what were historically recognized as the Alexandrian and Niagaran Series of the Silurian (Kluessendorf and Mikulic 1996).

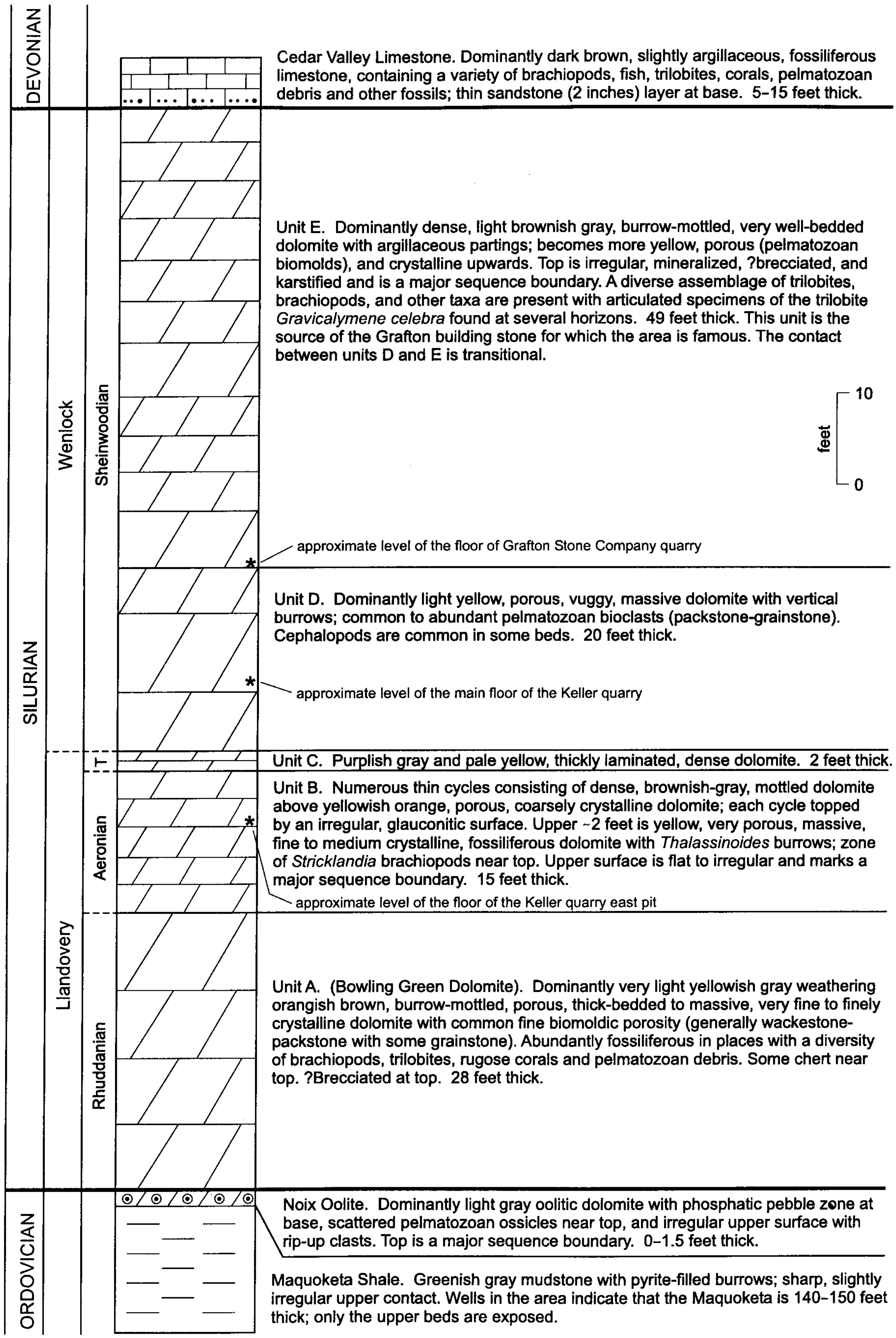

Figure 17 Stratigraphic section of Paleozoic rocks in the vicinity of Grafton quarries. Abbreviation: Telychian (T).

The succeeding unit C is equivalent to the Brandon Bridge Member of the Joliet Dolomite in northeastern Illinois and the Seventy-six Shale in southern Illinois and Missouri, based on the occurrence of the conodont *Pterospathodus amorphognathoides*. In the Grafton area, this unit is a very thin- to thin-bedded, very dense, very finely crystalline, purplish-gray to yellowish-gray dolomite; it is 2 feet (0.7 meters) thick. Thin zones of planar to slightly undulating, wavy to crinkly laminae interbed with bioclastic zones dominated by very fine biomoldic pelmatozoan debris in a wackestone to packstone texture. Pelmatozoan bioclasts occur sparsely in the laminated zones (mudstone-wackestone) as well. At Simms Hollow, a zone of orthoconic nautiloid cephalopods occurs near the base. Conodonts representing the *Pterospathodus amorphognathoides* Biozone occur in unit C in Simms Hollow (R. D. Norby, ISGS, 1999, personal communication). These strata may represent peritidal storm deposits. Unit C lithology changes abruptly into overlying unit D.

Unit D is equivalent to the early Wenlock Romeo Member of the Joliet Dolomite in northeastern Illinois and the St. Clair Limestone in southern Illinois and Missouri, based on lithologic and biotic characteristics as well as the presence of the conodont *Kockelella walliseri* (conodont information from R. D. Norby and M. J. Avcin, 1999, personal communication). No lithology equivalent to that of the Markgraf Member of the Joliet Dolomite, which normally overlies the Brandon Bridge in northeastern Illinois, is present here. Unit D is a very massive, rubbly, porous to vuggy, burrow-mottled, fine to medium crystalline, light yellowish-gray to medium gray (weathers white) dolomite, containing common to abundant fine pelmatozoan debris (generally a packstone to grainstone). Several zones of orthoconic nautiloid cephalopods are also present. Most notably, unit D is characterized by common, straight-sided, vertical burrows as much as 1 foot long, which may be filled with yellowish-orange dolomite or calcite spar. In the upper part of the unit, these burrows are shorter, more regularly aligned, and more closely spaced; they occur in cycles commonly capped by a thin laminated zone. These bioclastic packstones and grainstones probably were deposited under shoaling conditions; the abundance of deep vertical burrows suggests shifting sediments in a high-energy setting. The contact between units D and E is transitional; unit D is about 20 feet (6.5 meters) thick.

Unit E, representing the youngest Silurian (dominantly early Wenlock) strata present in the Grafton area, is equivalent to the Sugar Run Dolomite of northeastern Illinois and the Laurel Limestone of Indiana and Kentucky, based on lithologic and biotic characteristics, including the presence of the *Gravicalymene celebra* Trilobite Association (Mikulic 1999, Mikulic and Kluessendorf 1999b). It has been assigned erroneously to the Joliet and or Racine Formation by many authors, such as Savage (1926), Willman and Atherton (1975), and Garney (1983). These well-bedded strata, which are well exposed at the Keller Quarry (Stop 7), were the source of the famous Grafton building stone. Much of unit E, which is 49 feet (16 meters) thick, comprises dense, burrow-mottled, very finely crystalline, light brownish-gray dolomite with argillaceous partings. There is some cyclicity represented by more crystalline, more bioclastic interbeds. The skeletal mudstone-wackestone of the dominant lithology reflects a moderately diverse marine fauna dominated by a variety of brachiopods and trilobites, and articulated specimens of the trilobite *Gravicalymene celebra* occur at several horizons. Despite a long collecting history, little research has been done on the biota of these beds. Some of the Grafton trilobites were described in popularized articles by Whitney (1969a, b). Garney (1983) described the " Racine" biota from the Grafton quarries, but some of his taxa were derived from float representing all of the units exposed in the quarries. Consequently, his "Racine fauna" does not represent unit E exclusively. The upper part of unit E grades into a more porous, massive, yellowish-gray dolomite, containing fine biomoldic pelmatozoan debris (mudstone to packstone). Most of these strata appear to have been deposited in a quiet water, subtidal setting, indicated by the articulated nature of many of the fossils and the dominance of horizontal burrows; some of the upper strata were deposited under higher-energy conditions. The top of unit E, which marks the sequence boundary between the Silurian and Middle Devonian, varies from place to place, ranging from flat, mineralized, and bored to brecciated or karstified with large clay-filled solution cavities. Subsurface information indicates that this unit thickens by several meters to the east, where its upper beds and the overlying Devonian limestone are oil-stained.

The overlying Middle Devonian Cedar Valley Limestone is dominantly a dark brown, slightly argillaceous limestone, which is locally fossiliferous. Bioclasts include pelmatozoan debris, fish remains, trilobites, and a variety of brachiopods, especially *Leptostrophia* (Worthen 1868, McAdams 1885, Raasch 1947) and other fossils, generally in a wackestone texture. A few inches of sandstone occur at the base of the Devonian in places. The Devonian is quite variable in thickness (5 to 15 feet; 1.5 to 4.5 meters) regionally because of its unconformable upper and lower boundaries.

Grafton Trilobites

Fossils have been as much a part of Grafton's heritage as its stone quarries. For more than 150 years, it has been one of the most famous Midwestern collecting sites for trilobite fossils. At a minimum, thousands of specimens have been found in the Silurian rocks here by amateur collectors, professional geologists, quarry workers, and the general public. Most major natural history museums in the United States have Grafton trilobites in their collections or on exhibit.

The reason for the notoriety of this locality has been the abundance of complete specimens of the trilobite *Gravicalymene celebra* in the building-stone beds. Although more than twenty trilobite species are known from here, only *Gravicalymene celebra* is commonly found complete, and it is the most conspicuous fossil in these rocks. In 1916, Percy Raymond of the Museum of Comparative Zoology at Harvard University named this widely distributed species from specimens collected at Grafton. As early as the 1860s, quarry workers were selling specimens of this trilobite to interested parties as a way to supplement their income. Worthen (1876) reported, "These quarries have afforded fragments of some half dozen species of Trilobites only one of which, however, is abundant. This is the common *Calymene Blumenbachii*, of which the quarrymen obtain a great many, which they sell for a trifling sum. They call them stone dogs, but their resemblance to a dog is not very apparent." In 1906, G. K. Greene described the same Grafton enterprise stating that, "the quarry-men and boys carry them about in their pockets and sell them to visitors as 'rock dogs (dawgs)'." Some traditions live a long life, and, in 1975, the last of the Grafton quarrymen still called specimens of *Gravicalymene celebra* "rock dogs," but they no longer sold them. A few local residents continue to use the name.

Another less common, but conspicuous, trilobite, *Bumastus graftonensis,* was also named from a Grafton specimen (Meek and Worthen, 1870). The trilobites found in the building-stone beds are diverse and belong to the *Gravicalymene celebra* Trilobite Association (Mikulic 1999). In addition to *Gravicalymene celebra* and *Bumastus graftonensis*, *Arctinurus* sp., *Bumastus* sp., *Ceratocephala* cf. *goniata, Cerauromeros hydei, Cheirurus* cf. *niagarensis, Cybantyx* cf. *cuniculus, Dalmanites illinoisensis, Dalmanites platycaudatus, Deiphon americanus, Dicranopeltis decipiens, Encrinurus egani, Eophacops handwerki, Harpidella* sp., ?*Hemiarges* sp., *Illaenoides triloba, Lygduzoon arkansana, Mackenziurus lauriae, Ommokris obex,* ?*Planiscutellum* sp., *Pseudogerastos handwerki, Sphaerexochus* cf. *romingeri, Staurocephalus obsoleta*, and *Trochurus welleri* are all found in these strata. This association is widespread throughout the Midwest (northeastern Illinois, Wisconsin, Indiana, Kentucky, and Ohio), occurring in Wenlock strata representing a similar type of environment. As is typical for other occurrences of this association, more than 75% of the trilobite specimens found in these beds are articulated individuals of *Gravicalymene* oriented convex side up. These specimens are preserved in a molting position and do not represent dead trilobite carcasses (Mikulic 1994). With the exception of the cheirurids few other taxa are typically found complete. Unfortunately, trilobites are extremely difficult to find now that the quarries have been abandoned and the main productive layers near the middle of the quarry wall are inaccessible.

The brachiopods from these beds are diverse and include *Dicoelosia, Resserella, Leangella, Leptaena,* and *Antirynchonella*. Rugosid corals, small favositid corals, fenestrate bryozoans, and small gastropods are also typical. The small crinoid *Pisocrinus* is common, and pelmatozoan debris composes much of the fine bioclasts in these strata. Cephalopods were among the most conspicuous, if somewhat rare, fossils found in unit E while it was being quarried. As a result, several taxa were named in Grafton's honor using specimens collected in the quarries. These include *Lituites graftonensis* Meek and Worthen 1870), which was later used as the genotype for *Graftonoceras* named by Foerste in 1925, and *Dawsonoceras graftonense*, also named by Foerste in 1928. Apparently, *Graftonoceras* was never common, but, while the quarries were in operation, exceptional specimens of *Dawsonoceras graftonense* were found frequently.

Acknowledgments

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Stop Descriptions

Day 1

Stop 1: Casper Stolle Quarry—*Zakaria Lasemi and Rodney D. Norby*

Approximately the NW ¼ of Sec 13 and the NE ¼ of Sec. 14 extended, T1N, R10W; Cahokia 7.5-minute Quadrangle, St. Clair County, Illinois (Fig. 18).

The upper part of the Salem Limestone, the St. Louis Limestone, and most of the Ste. Genevieve Limestone are exposed in this 200-foot deep quarry (Figs. 19, 20). We will examine the Salem-St. Louis boundary, lower and upper St. Louis facies, the 'Lost River Chert' zone in the upper St. Louis, and the oolitic grainstone channel/shoal facies in the Ste. Genevieve Limestone.

Salem Limestone

Only the uppermost 25 feet of the Salem is exposed here (Fig. 19). The full Salem in this area is about 80–100 feet thick and consists of shoaling-upward cycles similar to, but thinner than, cycles seen at other quarries about 25 miles to the south. A core drilled from the floor of this quarry shows that the total Salem is 93 feet thick. The core also contains 82 feet of upper Warsaw, which is predominantly limestone with some dolomite and shale; an additional 68 feet of lower Warsaw is present that includes argillaceous limestone, argillaceous and silty dolomite, and shale.

The Salem-St. Louis contact is marked by a karstic, conglomeratic, and/or microbrecciated surface (Fig. 21A) similar to that present in other quarries in the area.

St. Louis Limestone

Both the lower and upper St. Louis are exposed here (Fig. 19). The lower St. Louis is dominantly a lime mudstone with some wackestone. Fenestral fabric, stromatolitic lamination, mud cracks, oncolites, and pelletal limestone are moderately common, and several microcrystalline dolomite beds occur at scattered intervals throughout the St. Louis. Two collapsed breccia beds are also present within the lower St. Louis in this quarry (Fig. 21B). These breccia beds commonly occur in this interval at the margins of the basin and have been interpreted to be the result of dissolution of underlying or interbedded gypsum and anhydrite (Collinson et al. 1954, Collinson and Swann 1958). The colonial coral *Acrocyathus* ("*Lithostrotionella*") occurs in the lower part of the lower St. Louis in this quarry (Fig. 21C). Similar corals occur at the same horizon in age-equivalent strata of the Salem in the Prairie du Rocher area, supporting the theory of lateral gradation between the lower St. Louis and Salem. Here, the lower St. Louis facies represents deposition in restricted lagoonal to intertidal-supratidal environments. Several oncolitic, peloidal, bioclastic packstone/grainstone beds, some of which are intraclastic at base, are also present within the lower St. Louis in this section; they probably represent tidal channel deposits.

The upper St. Louis is dominantly a normal marine facies, consisting primarily of bioclastic-peloidal wackestone and packstone interbedded with lime mudstone and some grainstone. The 'Lost River Chert' zone occurs at the top of the upper St. Louis (Fig. 19). An argillaceous, greenish gray lime mudstone (approximately 4 feet thick) occurs at the base of the upper St. Louis and marks the boundary between the upper and lower St. Louis (Fig. 19).

Ste. Genevieve Limestone

Here, the Ste. Genevieve Limestone is characterized by fine-grained, lenticular, cross-bedded, in part arenaceous, oolitic grainstone (Fig. 22A, C). Lime mudstone and dolomite are also present within the Ste. Genevieve. Several shaly beds containing well-developed oncolites (Fig. 22B) occur in the lower part of the Ste. Genevieve and may represent the transgressive facies deposited following the development of the upper St. Louis unconformity.

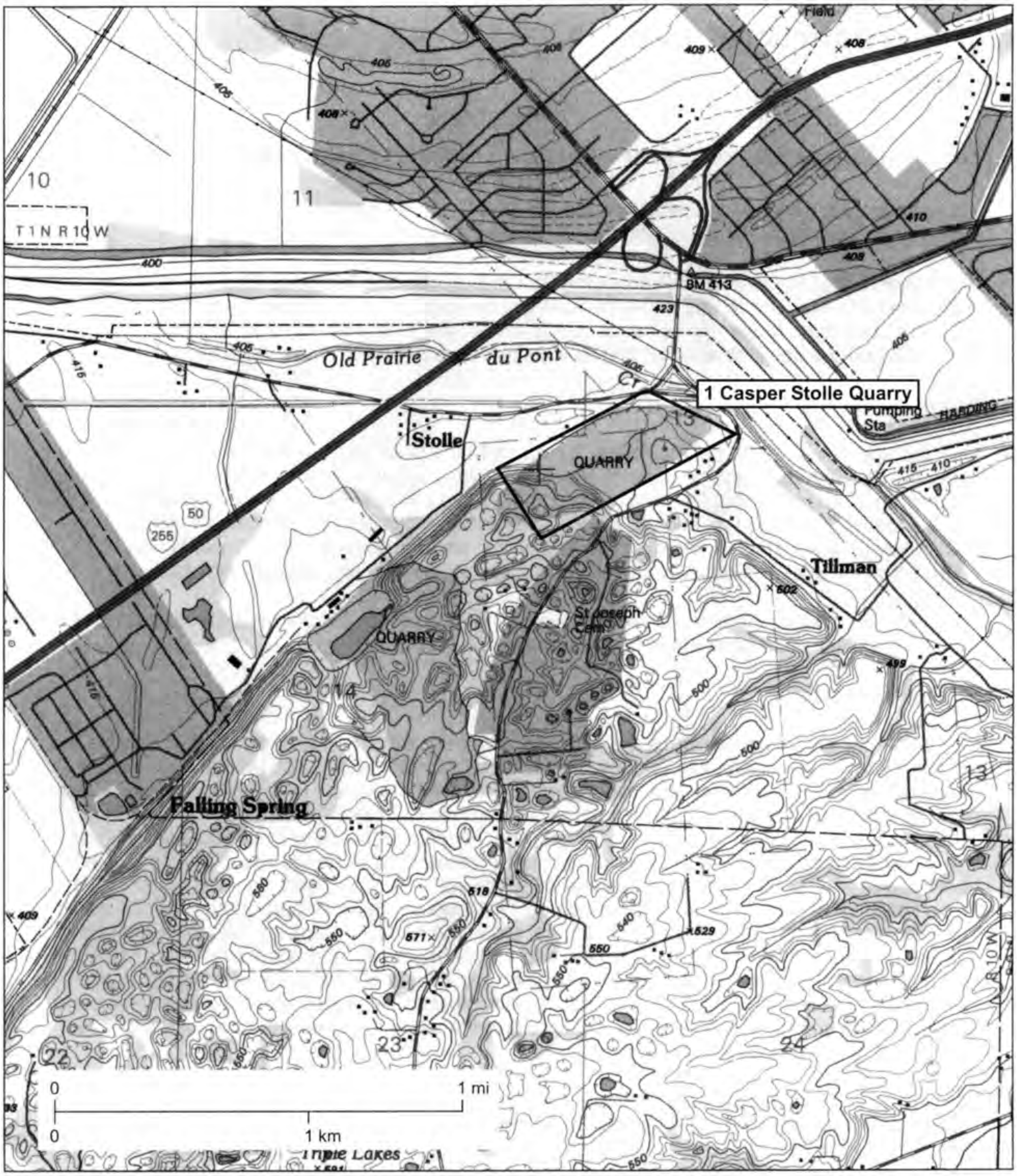


Figure 18 Location map of the Casper Stolle Quarry (Stop 1), approximately the NW of Sec. 13 and the NE of Sec. 14 extended, T1N, R10W; Cahokia 7.5-minute Quadrangle, St. Clair County, Illinois. (See also front cover for aerial view of this quarry and the surrounding area.)

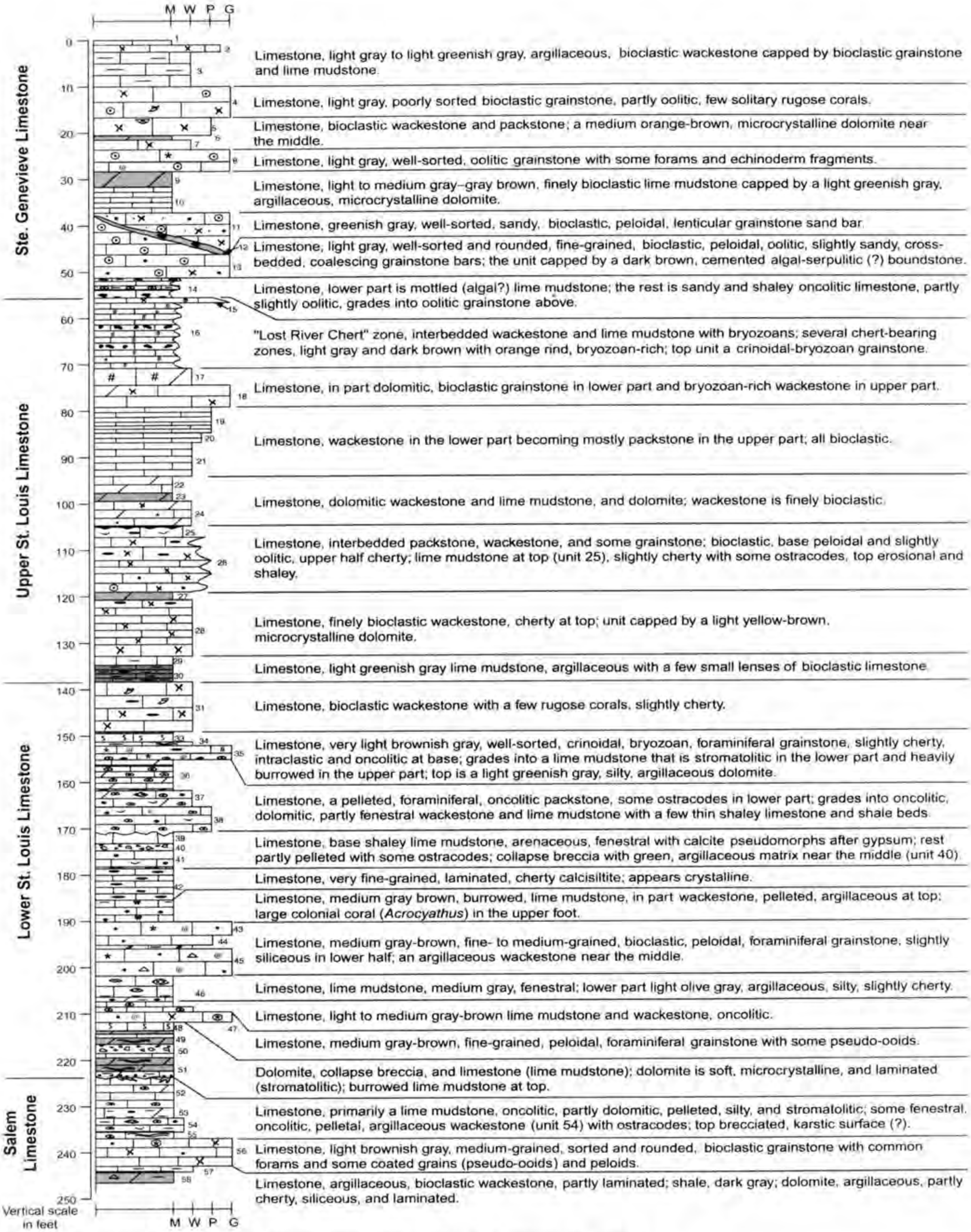


Figure 19 Stratigraphic column of Casper Stolle Quarry. Key for symbols on figure 20.

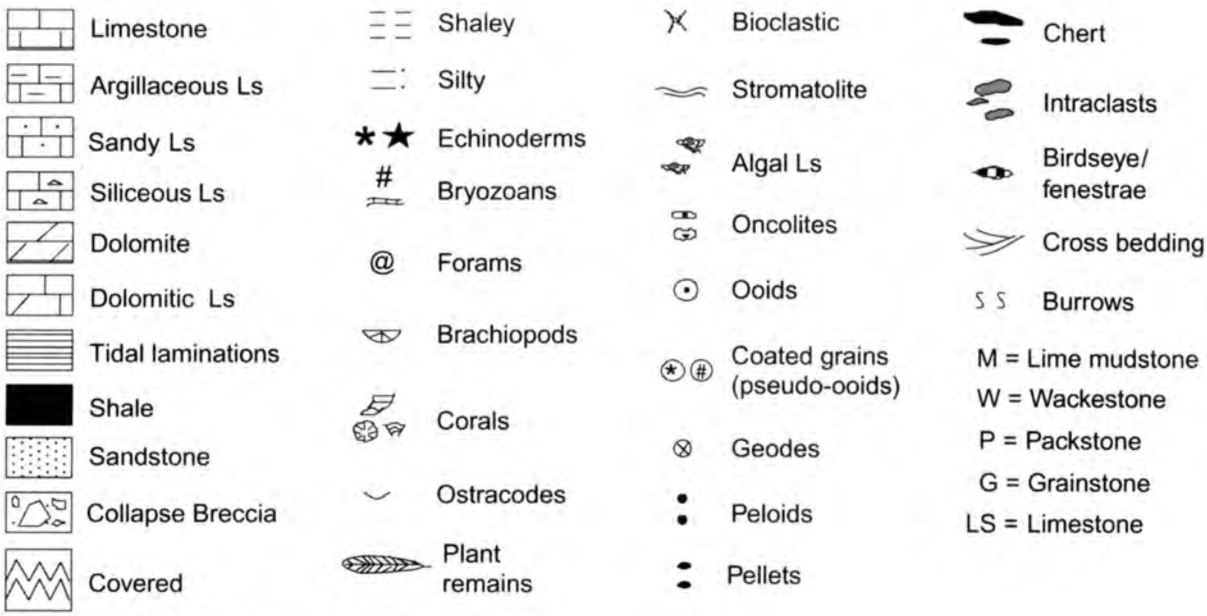


Figure 20 Key to figures 19, 32, and 37.

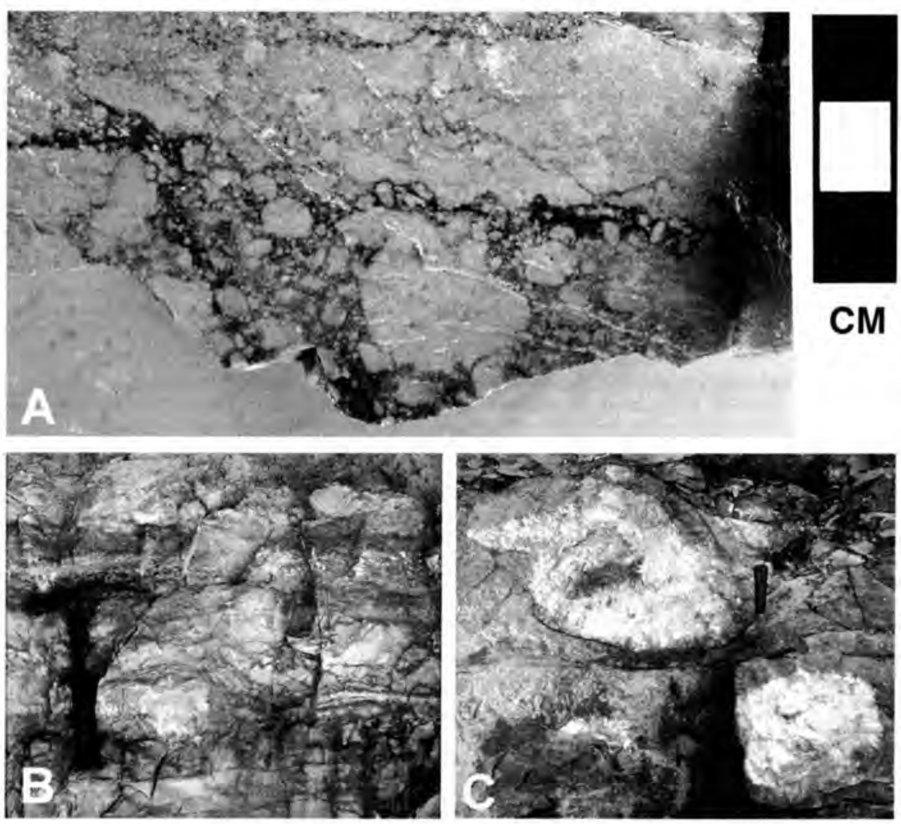


Figure 21 Features in the St. Louis Limestone at Casper Stolle Quarry. **A.** The Salem-St. Louis contact showing a brecciated surface similar to that in Waterloo quarry (Fig. 10). **B.** Collapse breccia in the lower part of the lower St. Louis Limestone; hammer head about 5.3 feet above the Salem-St. Louis contact. **C.** Colonial coral *Acrocyathus* (a.k.a. "*Lithostrotionella*") in the upper part of the lower St. Louis. Hammer is shown for scale.

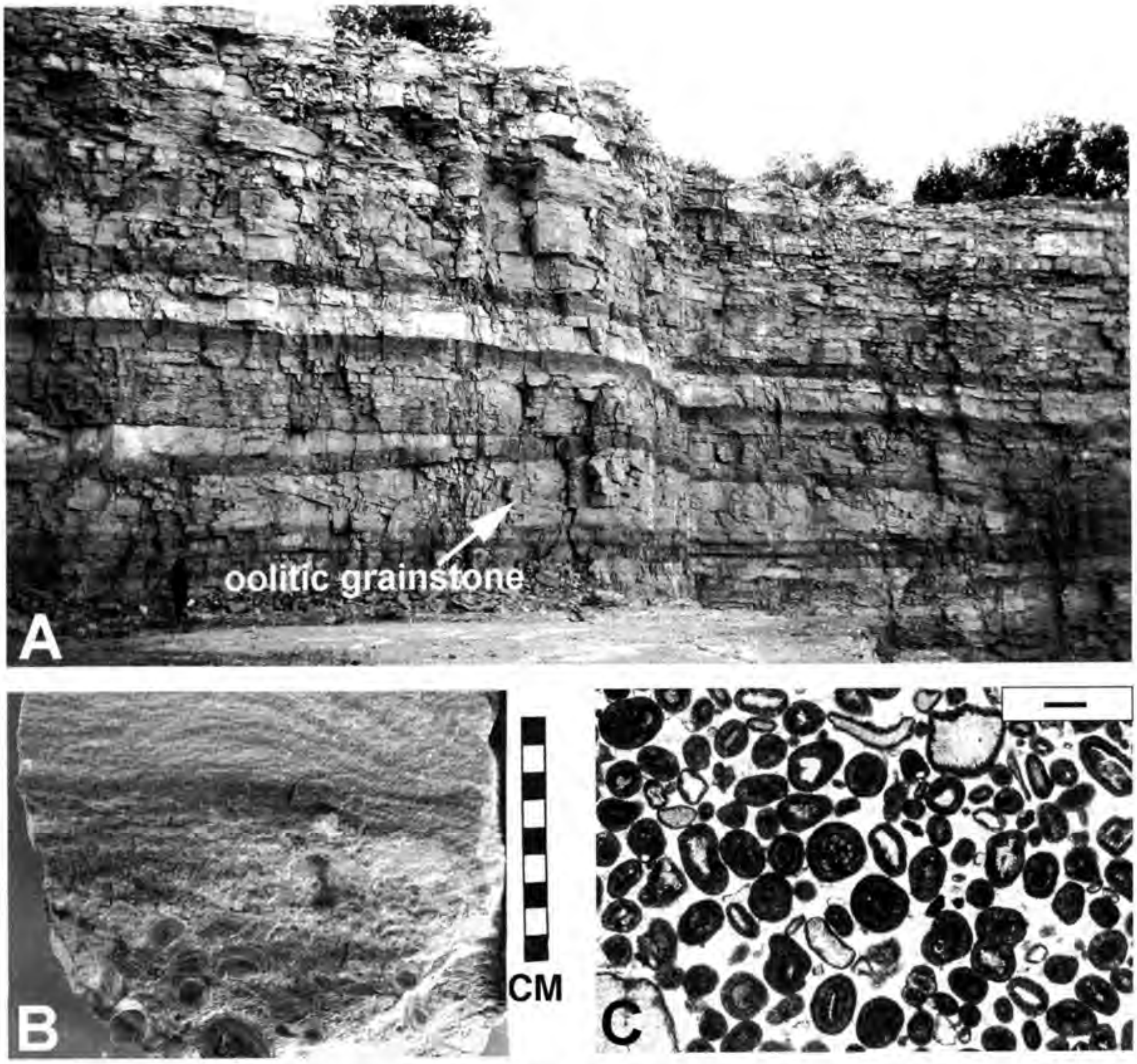


Figure 22 Features in the Ste. Genevieve Limestone at Casper Stolle Quarry. **A.** Ste. Genevieve Limestone at top of quarry, oolitic grainstone sandwave. **B.** Oncolitic lag overlain by an oolitic grainstone near the base of the Ste. Genevieve. **C.** Thin-section photomicrograph of the oolitic grainstone; Bar scale = 0.5 mm.

The formational contact between the St. Louis and the Ste. Genevieve Limestones lies immediately above the 'Lost River Chert' zone, a bryozoan-rich lime mudstone, wackestone, and chert interval at the top of the St. Louis. This contact has been difficult to recognize at many sections, including this one, because of similar lithologies in both units. However, the conodont data of Rexroad and Collinson (1963) and additional conodont data collected during recent studies at this quarry aided in recognition of the lithologic contact between the St. Louis and the Ste. Genevieve Limestones. The last appearance of the conodont *Synclydognathus geminus* (Hinde) at the top of the 'Lost River Chert' zone (Norby and Lasemi 1999) indicates a time break between the two formations. Therefore, we have placed the top of the St. Louis at the top of the distinctive 'Lost River Chert' zone in this area.

The oolitic facies of the Ste. Genevieve Limestone has been one of the most prolific hydrocarbon reservoirs in the Illinois Basin. In many areas in the subsurface, these grainstones are also underlain by a sucrosic dolomite that produces oil in some fields (Choquette and Steinen 1980).

Stop 2: Prairie du Pont Section—*David A. Grimley*

SE NW NE Sec. 21, T1N, R9W; French Village 7.5-minute Quadrangle, St. Clair County, Illinois (Fig. 13, 23).

The Prairie Du Pont Section, exposed in a large cutbank on the south side of Prairie du Pont Creek (Fig. 23), lies on a highly dissected portion of the Illinoian till plain in the St. Louis Metro East area (Figs. 13, 14). The site was first discovered in 1998 by Brett Denny (an ISGS bedrock geologist) and exposes a classic sequence of Wisconsinan loesses overlying Illinoian till and lacustrine deposits and a well-expressed Sangamon Geosol.

Site Description

The upper portion of this section (Fig. 24) consists of the two extensive Wisconsinan loess units (Peoria and Roxana Silts). Some of the Peoria Silt has been truncated along the hillside; total loess thickness is about 30 feet on nearby hilltops, whereas the total thickness here is 15 feet. Underlying the loess deposits is a relatively thin exposure (6 feet) of Glasford till (loam diamicton) and sandy sorted sediment, both of which are altered by the Sangamon Geosol. Some sand channels are found in the upper and lower portions of the Glasford Formation, deposited during the Illinoian Stage. The Sangamon Geosol is well developed in a silt unit about 3 feet thick that is probably a late Illinoian loess deposit. The Sangamon Geosol is predominantly reddish-brown silty clay loam and is typical of moderate to well-drained interglacial soil profiles, containing numerous clay skins and some mottling.

The basal 19 feet of this section consists of a locally significant lacustrine unit known as the Petersburg Silt (Fig. 25). This unit is predominantly crudely bedded silt and is probably composed largely of redeposited loess. The upper 1–2 feet is oxidized olive-brown. Below this, the silt is gray, calcareous, and fossiliferous and contains occasional erratic pebbles, interpreted as dropstones which are derived from melting icebergs .

Detailed Description of Prairie du Pont Section (Field Site FRV 15f)

Elevation is approximately 485 feet at the section top and 445 feet for nearby bedrock. The section was first described in November 1998.

0–7 feet Peoria Silt, silt loam, yellow-brown, oxidized, eroded at top (thicker up onto hill).

7–15 feet Roxana Silt, silt loam, pinkish-brown, oxidized.

15–21 feet Glasford Formation, pebbly loam to clay loam diamicton with scattered sand channels, leached, contains the Sangamon Geosol; upper half contains Bt horizon of Sangamon Geosol, mottled, 7.5YR 5/6 to 2.5Y 5/2, with silans; upper 1 foot has a layer of weathered sand and gravel about 4 inches thick, organic stains in fractures, and blocky structure that fines upwards; interpreted to be weathered till with some proglacial outwash and subglacial channel fill deposits.

One R-channel fill (a subglacial channel cut upwards into the ice) was found at the east end of the outcrop, about 7 feet high by 4 feet wide and filled with well-sorted fine to medium sand, moderately calcareous; under the base of the channel, fill is 3 inches of distorted and eroded diamicton; Because the channel is overlain by 3 to 4 feet of weathered till, the sand is deemed to be of subglacial origin.

21–40 feet Petersburg Silt, silt loam, contains sparse pebbles in some zones with some being erratics, mostly gray to gray-brown (10YR 5/1) but oxidized in the upper 1 foot (2.5Y 6/4), thickly bedded to crudely laminated, many bedding planes are broken or contorted, perhaps from overriding of the glacier following the deposition of this silt; fossiliferous with gastropods and fingernail clams abundant in some zones; snails are mainly helical and mostly aquatic species; conifer wood fragments (identified as spruce [*Picea*]) are present throughout but more common and larger towards the base of outcrop near the creek level;

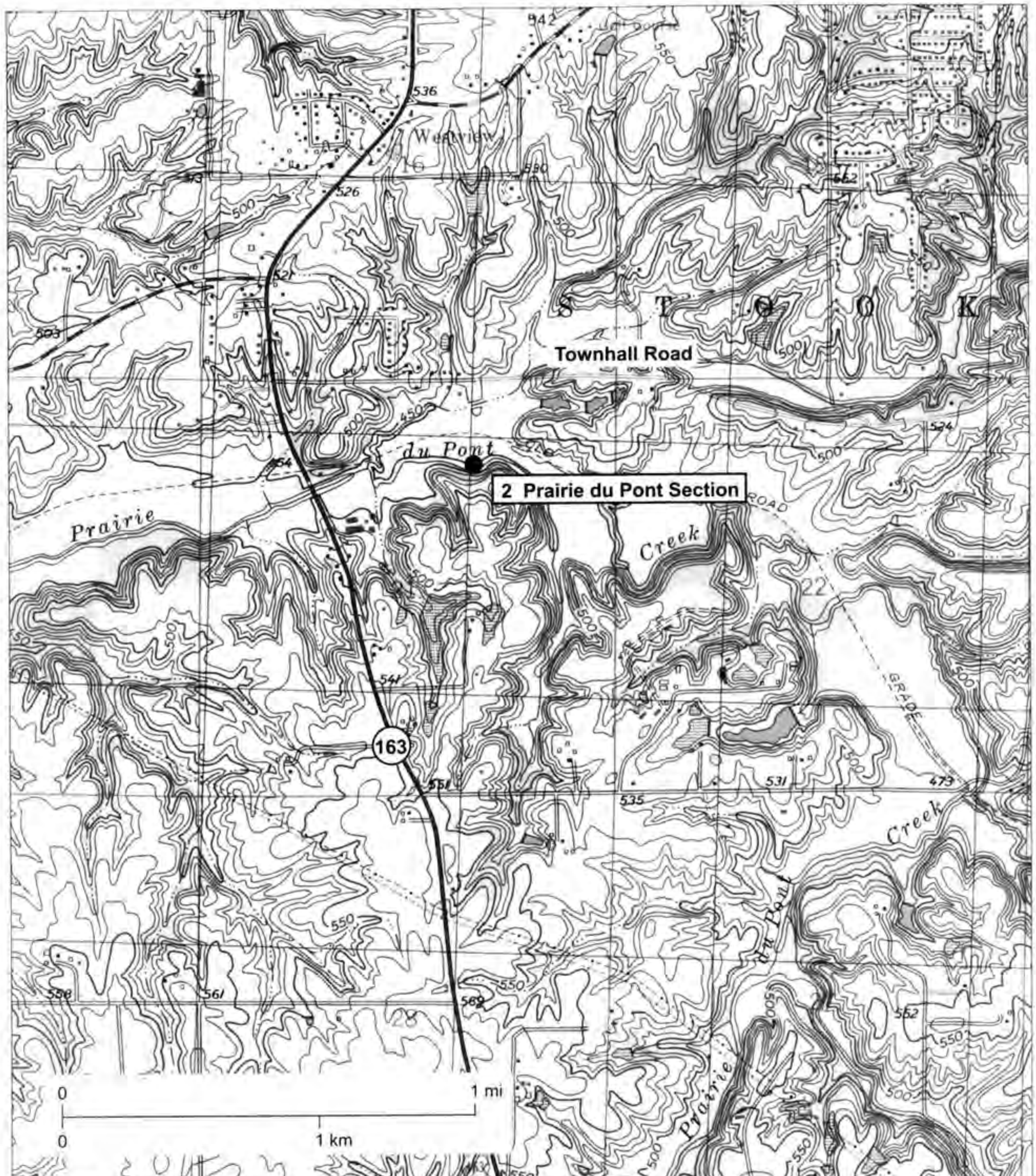


Figure 23 Location of the Prairie du Pont section (Stop 2), SE NW NE Sec.21, T1N, R9W; French Village 7.5-minute Quadrangle, St. Clair County, Illinois (Fig. 13).

some small logs are present and up to 3 inches in diameter and several inches in length; one large log (spruce/larch) was found to be 4 feet long and 9 inches in diameter, and its length continued into the outcrop; a few ostracodes were found in sieved samples; one was identified by B. B. Curry (ISGS) as *Cypridopsis vidua*, which lives in shallow water environments sourced by groundwater and occasional flooding.

Gastropods and Bivalves in the Petersburg Silt

Fossils are mainly aquatic gastropods (*Lymnae, Gyralus, Pomatiopsis,* and *Catinella*) with some terrestrial genera of gastropods (*Hendersonia*) as well as some aquatic bivalves (*Pisidium* or fingernail clams), all of which range from about 2 to 6 mm in length or width. Identifications were based on photographs in Leonard and Frye (1960); some identifications were by Eric Oches (University of South Florida). *Pomatiopsis* is a genus common in areas of moist land or in shallow water with freshwater plants (Baker 1931). Terrestrial gastropods, such as Hendersonia, were probably washed into the lake. One other ostracode species was identified (*Cypridopsis vidua*) that also indicates a shallow water environment. Amino acid ratios (alleoisoleucene/isoleucene peak heights) on gastropod (*Pomatiopsis* and *Catinella*) and bivalve (*Pisidium*) shells from the Petersburg Silt are generally in the range of 0.16–0.19 (courtesy of Eric Oches, University of South Florida, 1999). These results are typical for Illinoian age deposits in the region (Miller et al. 1994).

Oriented Spruce Logs in the Petersburg Silt

During repeated visits to the site in 1998 and 1999, several spruce (*Picea*) wood fragments (identified at the U.S. Department of Agriculture Wood Anatomy Research Lab, Madison, Wisconsin) were found scattered throughout the Petersburg Silt. Large spruce logs, 4 to 5 feet long and several inches in diameter (Fig. 25), found in basal portions of the silt, were oriented in a similar direction, probably parallel to the paleocurrent direction of the slackwater floods.

The considerable thickness of fine-grained lacustrine sediment and diamicton was conducive to excellent preservation of the logs. Many logs contain intact bark (Fig. 26), suggesting a still lacustrine environment with only very slow moving waters (consistent with a slackwater environment).

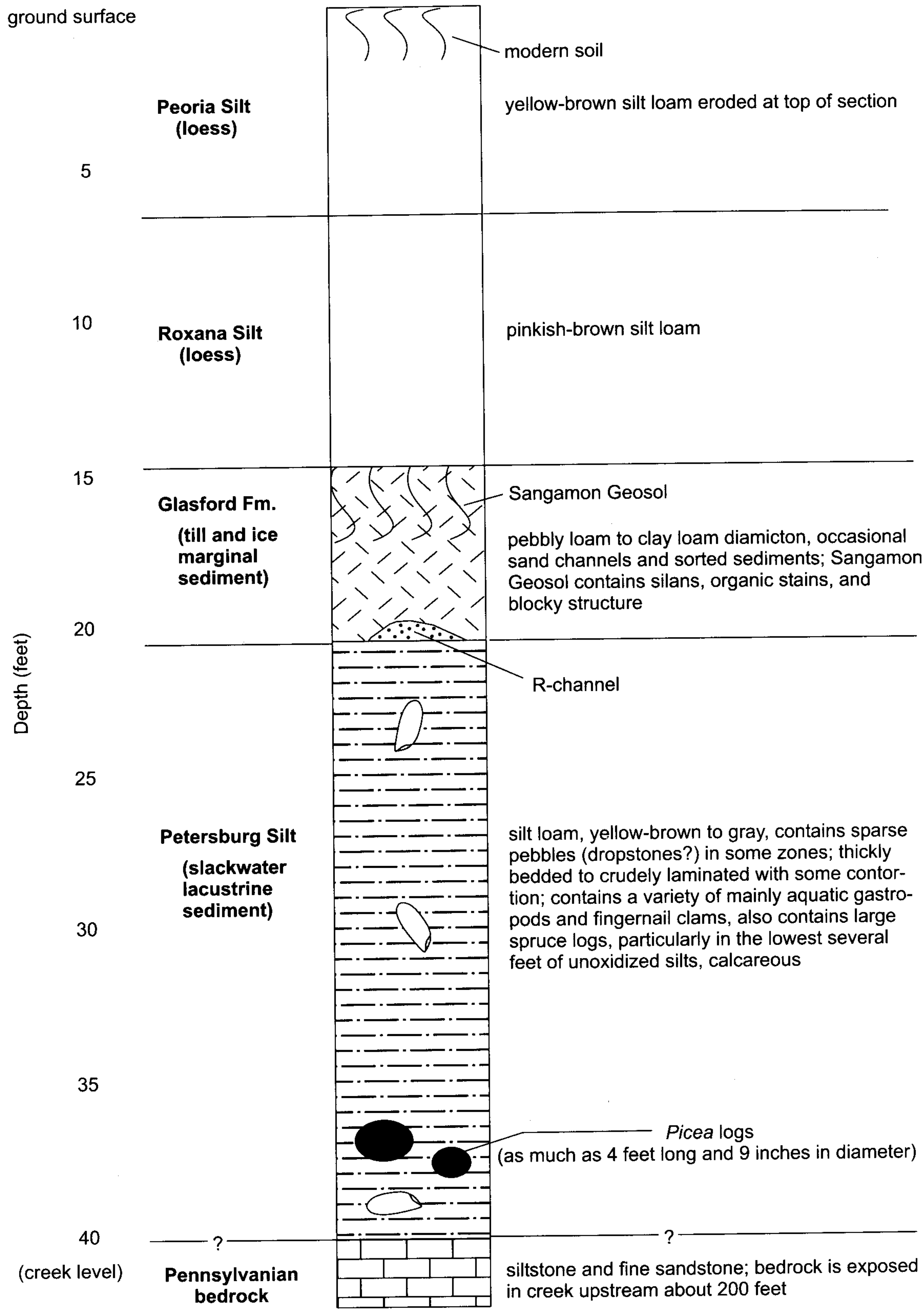


Figure 24 Stratigraphic column summarizing findings at the Prairie du Pont Section (Stop 2).

Figure 25 View of the lower portion of the Prairie du Pont section, showing the Petersburg Silt with its vague laminations, sparse distribution of pebbles, and wood fragments.

Figure 26 Close view of a well-preserved spruce (*Picea*) log with preserved bark from the Prairie du Pont Section, suggesting very still lacustrine conditions.

Stop 3: Camp Vandeventer Karst Area—*C. Pius Weibel*

SW SE SE of Sec. 21, T2S, R10W; Waterloo 7.5-minute Quadrangle, Monroe County, Illinois (Fig. 27)

Camp Vandeventer is owned by the Boy Scouts of America and provides camping, swimming, hiking, and other outdoor activities amid an intensely karstified and picturesque landscape. The camp straddles Fountain Creek, a relatively large stream that has dissected the sinkhole plain, which in this area is developed primarily in the St. Louis Limestone. The camp is in a truly unique geological setting that contains many sinkholes, a karst window, several caves and springs, and a seasonally sinking and rising stream (Fig. 27).

The geomorphology of the camp and the surrounding area consists of a mixture of features characteristic of both karst terrain (subsurface drainage) and fluvial terrain (surface drainage) and can be referred to as fluviokarst (White 1988). Most karst regions contain some component of fluviokarst, particularly on the borders of the region. The entire St. Clair-Monroe-Randolph County karst area was probably once covered by a mantle of Pleistocene drift and loess. Fluvial drainage systems that developed on this mantle became superimposed and gradually removed the mantle in some areas, including Camp Vandeventer. In these areas, the surface drainage pattern often is disrupted, and bedrock karst features are more common.

Sinkholes

Trout Camp Road, the entrance road to Camp Vandeventer, winds around and between numerous sinkholes, the most noticeable features of this karst region. These sinkholes, along with those within the campground, display a wide range of aspects: sizes from small to large, depths from shallow to deep, moisture conditions ranging from dry to wetland to ponded, and vegetation ranging from open to heavily forested. Ponded sinkholes form when eroded soil and other debris block the drain. The longevity of ponded sinkholes is unpredictable, as the drain plug may collapse, leading to a draining of the pond, which may occur slowly or catastrophically (e.g., Panno et al. 1999). Failure of the plug may be caused by a sudden increase of the hydrostatic pressure after a heavy rainstorm or snow melt or by turbulent flow in the conduit below the ponded sinkhole, which erodes the plug from the bottom.

The karst window (Fig. 28), across from the Apache Campground, is a special type of sinkhole that results from the total collapse, up to the land surface, of the roof of a cave. Karst windows are a relatively uncommon feature; this site is an excellent example. The water flowing through this "window to the underground" continues as an underground cave stream and discharges at the spring at base of the bluff just below the Camp Vandeventer mess hall (Aley and Aley 1998). After heavy precipitation events, this sinkhole may fill, and the water will overflow the rim at the north edge. When this condition occurs, the sinkhole briefly becomes a resurgence, or the site where an underground stream comes to or returns to the surface. The resurgence overflows into a small channel that flows under the entrance road and cascades down a ravine to a tributary of Fountain Creek. Recent slumping along the edges of this sinkhole indicates that during these periods of high water, significant erosion of the overlying Quaternary deposits occurs.

A perennial resurgence occurs to the west of the entrance lane, outside of the Camp Vandeventer property (Fig. 27). The resurgence stream is the same as the Fountain Creek tributary into which is fed the overflow from the karst window.

Springs

The spring at the base of the 12- to 14-meter (39- to 46-feet) high bluff below the camp mess hall is relatively large and discharges from a small cave in the St. Louis Limestone (Fig. 29). The discharge of this spring, known as Camp Vandeventer Spring, was measured at about 34.7 liters per second (550 gallons per minute) at near base flow (Aley and Aley 1998). The spring flows directly into Fountain Creek through an entrenched channel and, at one time, was a water source for the

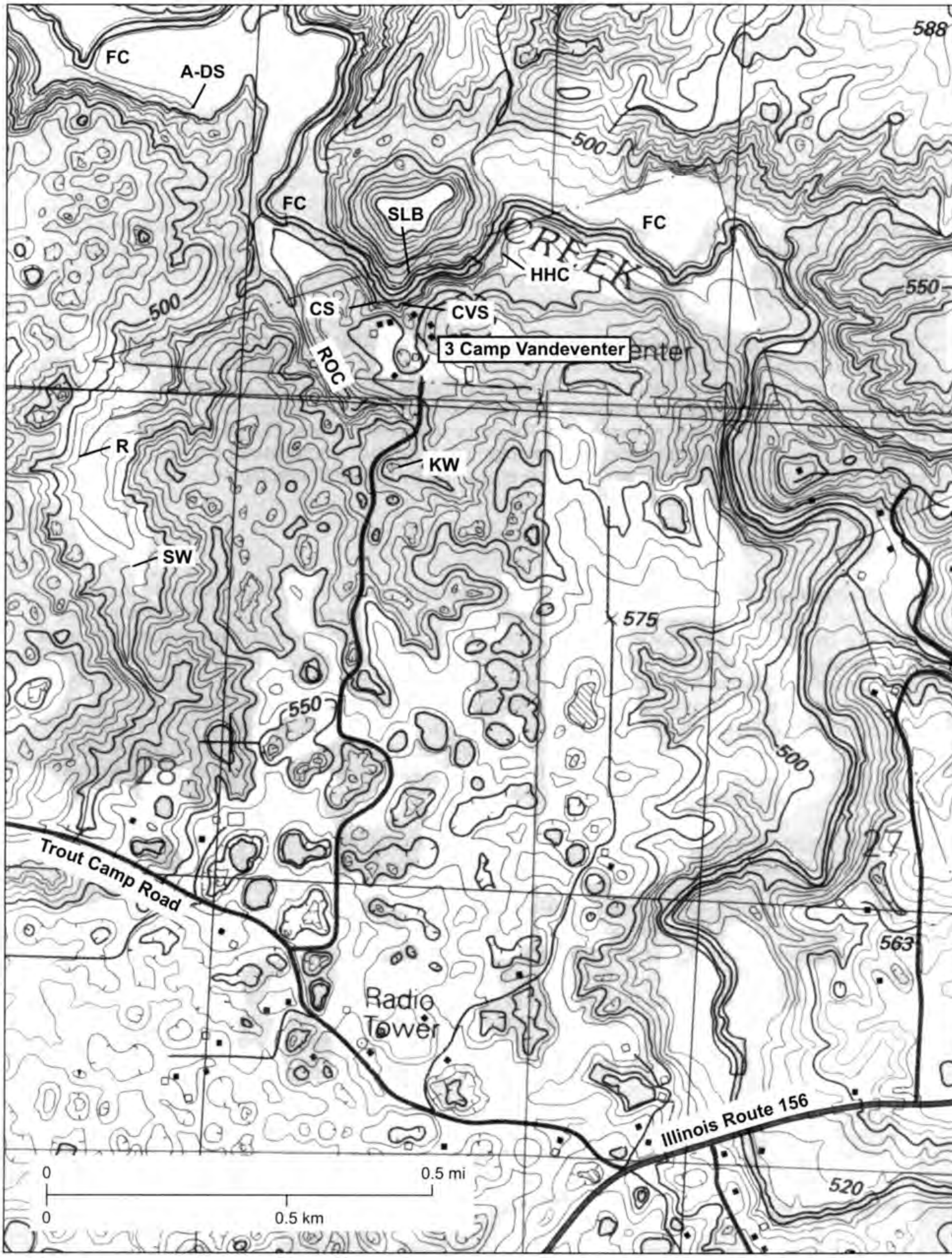


Figure 27 Topographic Map of Camp Vandeventer area (Stop 3) showing various karst features. Abbreviations: FC, Fountain Creek; A-DS, Annbriar-Dual Spring; SLB, St. Louis bluff; HHC, Hidden Hand Cave; CVS, Camp Vandeventer Spring; CS, unnamed cave spring; ROC = resurgence overflow channel; R = resurgence; SW = swallow hole; KW = karst window. The sinking and rising sites on Fountain Creek are not shown.

Figure 28 The karst window (KW on Fig. 27) at Camp Vandeventer across the entrance road from the Apache Campground. This feature was formed by the collapsing of the roof of the cave through which the water flows. This cave stream discharges in Fountain Creek at Camp Vandeventer Spring below the camp mess hall.

Figure 29 Camp Vandeventer Spring (CVS on Fig. 27) is a typical large cave spring in southwestern Illinois. Groundwater discharges from a small cave at the base of a bluff composed of St. Louis Limestone. The spring is discharging during a storm pulse.

camp. Like most springs in the sinkhole plain, the water from this spring is contaminated with fecal coliform bacteria and is one of the most severely contaminated springs in the sinkhole plain (Panno et al., unpublished data). Contact with the water should be avoided; the high abundance of *Escherichia coli* in the spring water indicates that private septic systems are a primary source of the bacteria (ibid.). The presence of optical brighteners in the spring water further supports these findings (Joan Bade, Illinois Department of Natural Resources, 1997, personal communication).

Another cave spring is located just to the west of this spring along the same bluff. Most of the time, the discharge from this spring is almost negligible. The spring is an overflow for the Camp Vandeventer Spring during flooding events (Panno et al. 1996) when the discharge is a characteristically high-energy, turbulent flow, and both springs discharge tens of thousands of gallons per minute. Another nearby large spring, Annbriar-Dual Spring, is located downstream and outside of Camp Vandeventer (Fig. 27).

Sinking (Losing) and Rising Stream

Fountain Creek is the largest stream in Monroe County, and, as is typical for karst terrains, has a reputation for being transformed into a raging torrent in a short period of time. Rainfall and snow melt on the limestone plateau flow into nearby sinkholes and discharge into Fountain Creek at numerous springs at the base of the bluffs along the creek (Fig. 27). These drainage systems are part of several unmapped groundwater basins that drain into the creek. Because the creek has dissected the limestone bedrock, it is the primary drainage channel for both surface and subsurface water.

At times of low flow, Fountain Creek is a sinking (losing) stream. Sinking streams occur when some or all of the surface stream flow is diverted into the subsurface drainage system. Voris (1998) reported that the stream may flow completely underground (during particularly dry periods) a few hundred meters (yards) downstream from the camp mess hall. The creek water rises to the surface channel about 0.4 kilometers (0.25 miles) downstream and eventually flows into the Mississippi River, about 16 kilometers (10 miles) west of the camp. In this case, the diversion of water into the subsurface occurs within the gravel bed of the stream and a swallow hole is not present. A swallow hole (or swallet) refers to the pit or opening where a sinking stream goes underground. A swallow hole occurs to the west of the entrance lane, outside of the Camp Vandeventer property (Fig. 27). The water source for this stream is Mays Spring, which is located a short distance to the southwest. Discharge from Mays Spring varies from a trickle to a pronounced, almost eruptive boiling.

Caves and Conduits

There are at least three cave openings at Camp Vandeventer. Camp Vandeventer Spring and the adjacent overflow spring are both cave entrances and discharge points of a groundwater basin that drains an unknown (but probably relatively large) area directly to the south of the camp. The former cave is not accessible at this site, but the latter cave can be explored, although the passages are not very large. A third cave, Hidden Hand Cave, is upstream (northeast) from the springs and can be reached by following the paths along the south side of Fountain Creek. Hidden Hand Cave also is a cave spring, although the discharge is generally low. The cave entrance is accessible unless Fountain Creek is at flood stage.

Across Fountain Creek and just upstream from the springs and the camp mess hall is a spectacular, natural bluff of St. Louis Limestone that displays numerous karst dissolution features (Fig. 30). The upper portion of the bluff contains vertical joints that allow surface water to move downward into the bedrock. Small amounts of water move laterally along bedding planes and may be seen discharging from the bluff wall and flowing down the bluff face. A small, sediment-filled cave passage occurs at the base of the bluff.

Figure 30 View of the outcrop of St. Louis Limestone along Fountain Creek, opposite Camp Vandeventer Spring (CVS on Fig. 27). The bluff displays incipient vertical and horizontal conduits that have developed along joints and bedding planes.

Stop 4: Columbia Road Cut—*Zakaria Lasemi, Rodney D. Norby, C. Pius Weibel, and Joseph A. Devera*

SE NE SE and NE SE SE Sec. 22, SW SW Sec. 23, and NE NW and SE NW Sec. 26, T1S, R10W, Columbia 7.5-minute Quadrangle, Monroe County, Illinois (Fig. 31)

The Warsaw Formation and Salem Limestone (Fig. 32) are exposed near the crest of the Waterloo-Dupo Anticline (Fig. 11) in a long road cut along Illinois Route 3 where it intersects Illinois Route 158 (Fig. 33A). Stratigraphically higher beds (upper part of the Salem and lower beds in the St. Louis Limestone) are exposed nearby as tilted strata in a small creek on the south side of Illinois Route 3 (Fig. 33B). Here, the St. Louis is mainly a lime mudstone with some stromatolitic laminations and fenestral fabrics ("birds eye") typical of the lower St. Louis facies in the area. It is difficult to find the contact between the Salem and St. Louis in this creek. At this stop, we will examine depositional facies and discuss stratigraphic and sequence stratigraphic relationships between the lower Warsaw, upper Warsaw, and Salem.

Warsaw Formation

Baxter (cited in Keene 1969) first described the main section as consisting of 15 feet of Salem overlying 14 feet of Warsaw Shale. Additional strata are exposed above and below Baxter's main section. The entire section was redescribed by Collinson et al. (1979), and the name Ullin Limestone was essentially substituted for the limestone portion (upper part) of the Warsaw Formation; a revised section was also given by Norby et al. (1989). It has been suggested that the carbonates overlying the shale of the Warsaw represent the feather-edge of the area of Ullin deposition.

After careful re-examination, both lithologically and petrographically, and comparison with other sections, we think that most of what was previously referred to as Ullin should be assigned to the upper Warsaw. This reassignment would support the opinions of Kammer et al. (1990) that, although the Ullin has general lithologic characters in common with the upper Warsaw, the upper Warsaw is the more appropriate term to use here. We recommend that the name Ullin be restricted to sections devoid of siliciclastics. We place the contact between the lower and upper Warsaw at a horizon where the shale-dominated interval grades into a carbonate-dominated (primarily a crinoidal-bryozoan grainstone) interval (Figs. 32, 33A). This horizon correlates with the disconformity surface we have found in the area (Fig. 2) and the faunal break reported by Kammer et al. (1990).

Here, the lower Warsaw is dominantly a shale with some crinoidal limestone interbeds. The lower Warsaw is exposed in a slope below road level on the north side of Illinois Route 3 and at the base of cuts on both sides of Route 3. Beds of argillaceous, silty, finely crystalline dolomite with small geodes of pink dolomite are also present. Some beds contain abundant brachiopods and bryozoans.

The upper Warsaw is exposed mainly on the south side of Route 3 (Fig. 33A) and is primarily a partly dolomitic, crinoidal-bryozoan grainstone in the lower 10–12 feet. This cross-laminated, crinoidal-bryozoan grainstone (Fig. 3A), which is lithologically similar to the upper Ullin in southern Illinois, laterally grades into shales and argillaceous dolomites similar to those in the lower Warsaw. Above this grainstone, Warsaw carbonates become better sorted, and some beds contain coated grains (superficial ooids or pseudo-ooids), suggesting a shallowing of the environment toward the end of upper Warsaw deposition. In west-central Illinois (e.g., Adams County) and southeast Iowa, this shallowing event was accompanied by subaerial exposure and erosion (Lasemi and Norby, see pages 8, 9).

Salem Limestone

A thin-bedded, cherty, siliceous, spiculitic limestone unit (Fig. 34) is present in this road cut that we think is equivalent to the "Fults" Member (Baxter 1960) of the Salem Limestone (Fig. 32, unit 12). This unit is a laminated, dolomitic, argillaceous, silty lime mudstone (Fig. 3C) with some bioclastic packstone/grainstone lenses. The interval is similar to the argillaceous, dolomitic, cherty unit that

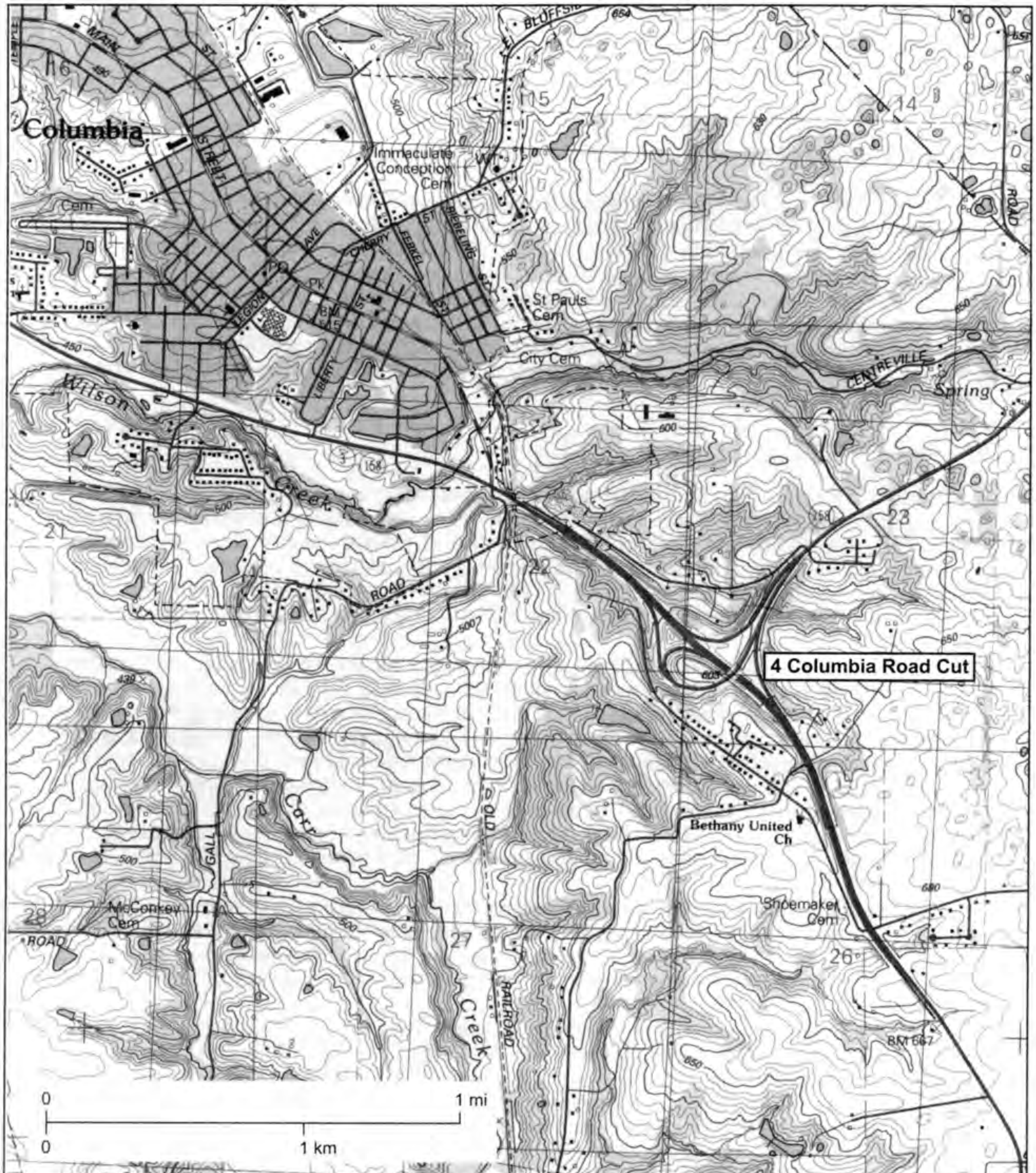
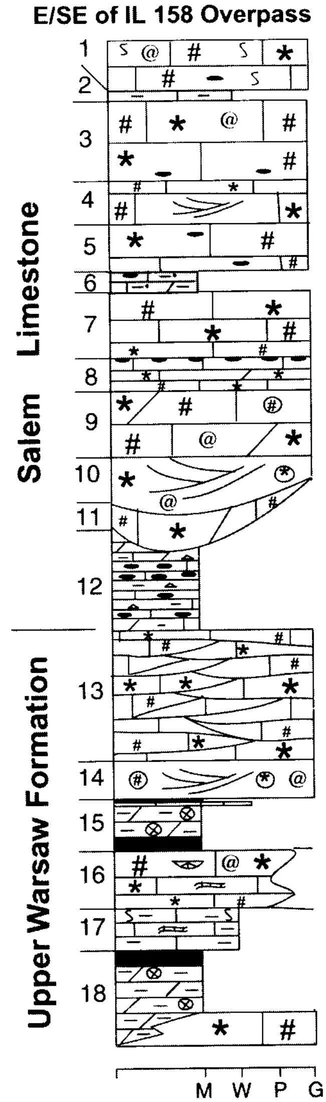


Figure 31 Location map of Columbia road cut (Stop 4) along IL Route 3, SE NE SE and NE SE SE Sec. 22, SW SW Sec. 23, and NE NW and SE NW Sec. 26, T1S, R10W, Columbia 7.5-minute Quadrangle, Monroe County, Illinois.



Salem Limestone

Units 1-9 (33.3 feet). Limestone, grainstone predominates, light brownish gray, weathers tan to light gray, fine- to medium-grained with some very fine- and coarse-grained, bioclastic, primarily echinoderm and bryozoan, rare forams and gastropods; Unit 1, heavily burrowed (*Thalassinoides*-type) in upper part; Unit 2, rusty weathering beds with some glauconite; Unit 3, a line of concentrically banded spheroidal to elongate chert near the base; Unit 4, cross-laminated; Unit 5, finely laminated with occasional chert and escape burrows; Unit 6, lime mudstone to wackestone, argillaceous and dolomitic with some chert; Unit 8, nodular chert bed at top; Unit 9, massive dolomite to dolomitic limestone, some coated grains (pseudo-ooids).

Units 10 and 11 (8.0 feet). Limestone, grainstone, medium gray fresh, weathers yellowish brown, very-fine to medium-grained, bioclastic as above and some pseudo-ooids (?), cross-bedded, probably a channel; Unit 11 partially dolomitized, channelized into underlying unit.

Unit 12 (6.0 feet). Limestone, mostly lime mudstone with some dolomite, brown to grayish brown fresh, tan to light-gray weathered, dolomitic in lowest and upper parts, siliceous, abundant sponge spicules, laminated, thin- to very thin-bedded; generally very cherty; cherts mottled white to light to dark gray to orange and brown. Unit ranges up to 9.5 feet because of channeling.

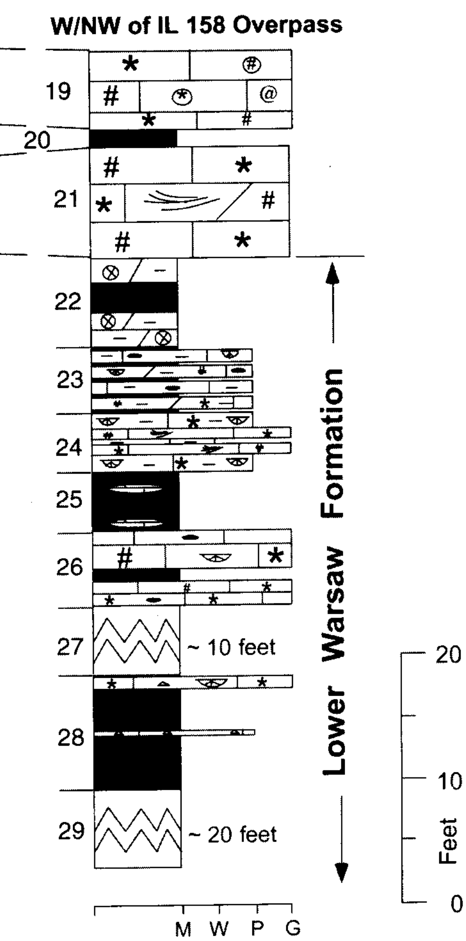
Upper Warsaw Formation

Unit 13 (10.5 feet). Limestone, light-gray, thin, nodular-bedded, medium-grained, moderately well-sorted, crinoidal-bryozoan grainstone; similar to Kidd Member (Baxter 1960).

Unit 14 (3 feet). Limestone, medium gray to brownish gray, medium to coarse, cross-bedded, crinoidal, bryozoan, and brachiopod grainstone, well rounded and moderately sorted with common coated grains and rare forams.

Units 15 (4 feet), 18 (4.5 feet), & 20 (0.7 feet). Dolomite, argillaceous to very argillaceous, light to medium olive gray to blue gray with small geodes and shale, dark blue gray, dolomitic (?).

Unit 16 (4.6 feet). Limestone, medium gray with reddish brown tinge, medium to coarse, bioclastic packstone with dolomitic matrix; allochems include crinoids, bryozoans (some large, encrusting type?), brachiopods, and rare gastropods and bivalves. Some rip-up clasts and/or scour-filled lime mudstone. Unit appears to be laterally equivalent to Unit 19.



Unit 17 (3.5 feet). Limestone, argillaceous, light olive gray, weathers very light gray, heavily burrowed at top, bioclastic (primarily crinoids, bryozoans, and brachiopods) wackestone and some packstone.

Unit 19 (6.5 feet). Limestone, gray to medium dark gray, medium-grained, bioclastic (echinoderms, bryozoans, brachiopods, and rare forams and gastropods) grainstone, moderately sorted, common coated grains near base.

Unit 21 (9.5 feet). Limestone, light gray, medium- to coarse-grained, crinoidal-bryozoan grainstone, poorly sorted, common lime mudstone rip-up clasts, laminated to cross-laminated.

Lower Warsaw Formation

Units 22-29 (66.7 feet). Shale, limestone, and argillaceous dolomite; shale, dark olive brown, light blue gray weathered, in part dolomitic; grainstone and some packstone, light to dark gray, gray to brown weathered, some green tinge, fine- to coarse-grained, often poorly sorted, bioclastic (primarily bryozoans and echinoderms), in part argillaceous and slightly glauconitic, many large brachiopods in some beds; laminated to cross-laminated (hummocky) in some beds, small calcite and chalcedony nodules, some siliceous zones; dolomite, mainly in Units 22 and 23, light olive gray, weathers tan, microcrystalline, silty, argillaceous; some pink dolomite and calcite geodes, locally fossiliferous, some silicified *Thalassinoides*-type burrows; a few very thin to nodular discontinuous chert and soft siliceous beds; approximately 30 feet covered (presumably shale) in lower part.

Figure 32 Stratigraphic column for Columbia road cut. See figure 20 for key.

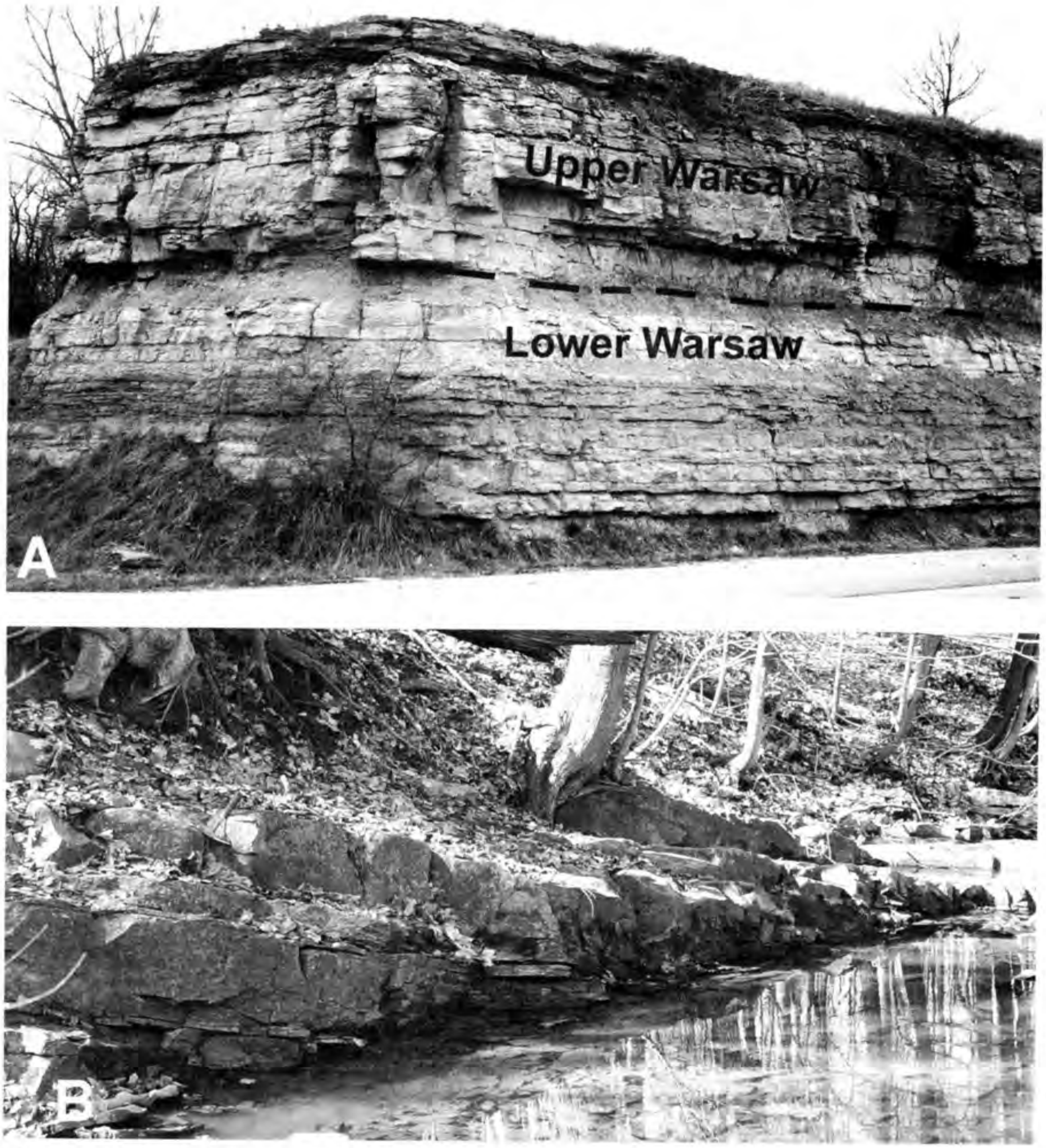


Figure 33 A. Columbia road cut showing part of the lower and upper Warsaw Formation. **B.** Creek section along IL Highway 3 showing tilted strata of the St. Louis Limestone.

Figure 34 Columbia road cut showing "Fults" Member of the Salem overlain by a bioclastic, slightly oolitic grainstone facies of the Salem.

regionally overlies the Ullin in the subsurface (Lasemi et al. 1998) and appears to be equivalent to the Somerset Shale (Benson 1976) that widely occurs at a similar horizon in Indiana and Kentucky.

Abundant sponge spicules and *Zoophycos* burrows (seen in drilled cores) along with the absence of any shallow water facies, suggest that this cherty unit was deposited in a relatively deep-water setting. Because of the widespread presence of this unit throughout the Illinois Basin and adjacent regions, we place the Ullin/upper Warsaw-Salem contact at the base of this cherty unit. We interpret this unit to represent a deepening event following deposition of the shallow-water facies of the uppermost part of the Warsaw and/or Ullin (Lasemi et al. 1998).

The rest of the Salem in this section consists of a bioclastic-peloidal grainstone. The grainstone facies of the Salem in this section was deposited as cyclic carbonate sand shoals and tidal channels. The grainstone facies consists of fine- to medium-grained, rounded and moderately sorted crinoidal-bryozoan grains. Forams, some peloids and rare coated grains (pseudo-ooids) are also present. Petrographically, the Salem here appears to be similar to the uppermost part of the upper Warsaw, indicating deposition in a generally similar environment.

Tilted beds (angles of 15–25°), representing parts of the upper Salem and lower St. Louis (Fig. 33B), occur in a creek bed adjacent to the south side of Illinois Route 3. There may be some repeated beds caused by faulting in this section. The tilted beds in the creek bed are part of the more steeply dipping western limb of the Waterloo-Dupo Anticline (Nelson 1995).

Karst Features

Because much of the area is mantled karst, many smaller and subtle karst features are not well exposed except in manmade exposures, such as at this field trip stop. The fractures, which have been enlarged by dissolution to allow the rapid transport of water into and through the bedrock, are well exposed at the top of this road cut in the Salem Limestone. As rain water and snow melt infiltrate the thin soil layer, it assimilates carbon dioxide and creates carbonic acid. This slightly acidic water infiltrates openings in the underlying limestone bedrock, and small amounts of calcite are dissolved by carbonic acid.

Figure 35 View of the contact between the top of the bedrock (Salem Limestone) and the overlying Quaternary sediments. Water percolating through the soil becomes more acidic and dissolves the limestone along joints. The joints have been enlarged by dissolution to the point where some of the rock has slid downward into the bedrock cavities. If the excavation for the highway had not taken place, this process would have continued and a small sinkhole likely would have formed. The darker surfaces of the rock are natural and show the effects of acidic groundwater etching, whereas the lighter surfaces are manmade and are the result of the excavation.

Dissolution at the upper surface of the bedrock commonly results in the formation of karren or small grooves separated by sharp to rounded ridges (Fig. 35). Dissolution of the limestone along joints in the Salem Limestone has resulted in well-developed vertical channels (known as grikes or cutters). Typically these features are filled with soil and act as small, local funnels for surface waters to move both downward and laterally into the ground water. Some of these grikes have enlarged and formed small sinkholes. These karst features are probably common throughout the area but are seldom seen because of the mantle of Pleistocene drift and loess and modern soil. These shallow buried features can cause significant engineering problems at construction sites because of the inherently irregular and unpredictable subsurface topography of the bedrock. These problems include excavation difficulties in areas with well-developed grikes, soil piping, differences in load-bearing characteristics of excavated surfaces, and solution cavity collapse.

Stop 5: Alton Bluff Section—*Rodney D. Norby and Zakaria Lasemi, leaders*

NW NE NW Sec. 14, NE NW NW Sec. 14, and SW SW Sec. 11, T5N, R10W, additional section present in SE Sec. 10, T5N, R10W; Alton 7.5-minute Quadrangle, Madison County, Illinois (Fig. 36)

This bluff section (Fig. 37) was first described in detail by Collinson et al. (1954), whose description has been used in a modified form in several later guidebooks (e.g., Collinson and Swann 1958). No specific exposure was ever designated as the type section for the St. Louis Limestone. However, Thompson (1986) indicated that the Alton Bluff section and exposures to the northwest of Alton are the best, most complete exposures of the St. Louis Limestone in the St. Louis Metro East area.

At this section, we will observe the uppermost beds of the lower St. Louis Limestone, the upper St. Louis, and the Ste. Genevieve Limestone (Fig. 38A), and we will discuss the beds previously termed "transition beds." Unfortunately, the beds of the Ste. Genevieve are essentially inaccessible, as are some beds in the upper St. Louis. Most of the beds of the lower St. Louis can be examined in various locations along the bluff to the northwest.

The upper part of the lower St. Louis is present as units A and B of Collinson et al. (1954) at the west end of the exposure (Fig. 37). The "main breccia" (unit A) is a highly brecciated interval consisting of angular pebbles to boulders, primarily of lime mudstone in a silty, argillaceous limestone matrix. The origin of the breccia has been related to dissolution of gypsum/anhydrite (e.g., Collinson et al. 1954). The timing of the dissolution event is not clear, but the event may possibly have occurred as a result of exposure to groundwater prior to deposition of the overlying beds (Collinson et al. 1954). This scenario is likely considering the very shallow marine setting (intertidal-supratidal) in which the lower St. Louis was deposited. Unit B is another brecciated bed, apparently an overlying bed that only partially collapsed. Unit C is a greenish gray, shaly limestone that we have identified as regionally marking the break between the lower and upper St. Louis.

In reviewing the conodont collections of Rexroad and Collinson (1963) and notes in our files, *Taphrognathus varians* and some transitional specimens between *Taphrognathus* and *Cavusgnathus* occur in units A and B. These species are characteristic of the lower St. Louis and beds near the contact between the lower and upper St. Louis. Conodonts indicative of the upper St. Louis include *Synclydognathus geminus* and *Cavusgnathus unicornis* (key species in the unrevised *Apatognathus scalenus-Cavusgnathus* Assemblage Zone of Rexroad and Collinson 1963). These latter species first appear in units C and D, although a few primitive forms are mixed in with some of the older fauna in the upper breccia or unit B (probably caused by brecciation). These conodont data correspond well with the boundary between the lower and upper St. Louis that we pick at the base of unit C.

The St. Louis-Ste. Genevieve "transition zone" (Collinson et al. 1954) was used particularly at this section because certain lithologic and faunal attributes appeared to be mixed, making identification of a formational boundary difficult. The base of the transition zone was drawn at the base of unit M (Fig. 37), which Collinson et al. (1954) described as an oolite and considered to be indicative of Ste. Genevieve sedimentation. Our samples and thin sections did not show any oolites and most of the rock is the peloidal, bioclastic grainstone that is common in the upper St. Louis. In units D, H, and N, the crinoid or stems of *Platycrinites penicillus* were noted by Collinson et al. (1954). These are generally considered a guide to the Ste. Genevieve, but they have also been noted in the St. Louis Limestone in the Ste. Genevieve, Missouri area (Weller and St. Clair 1928) and possibly in the Salem (Weller et al. 1948). Stems of *Platycrinites* sp. are also present in undisputed (based on conodont data) upper St. Louis strata at Waterloo quarry in southern Monroe County. Therefore, certain fossils and the general lithology may not be good indicators for identifying the St. Louis-Ste. Genevieve boundary.

Figure 36 Location map of Alton Bluff Section (Stops 5 and 6). Alton Bluff Section begins in NW NE NW Sec. 14, T5N, R10W, behind the ConAgra plant along Illinois Highway 100 and continues west into NE NW NW of Sec. 14 and into SW SW Sec. 11. Additional section is also present in SE Sec. 10, T5N, R10W, Alton 7.5-minute Quadrangle, Madison County, Illinois.

The key lithologic features that we use to separate the St. Louis from the Ste. Genevieve Limestone in this section include the thin-bedded, bryozoan-rich lime mudstone and wackestone of the Lost River Chert zone (unit N; Fig. 38B). The Ste. Genevieve contains well-developed oolitic grainstone. Locally, oncolitic algal beds appear to represent earliest Ste. Genevieve deposition. These features are similar to those present at Casper Stolle Quarry (Stop 1).

To reinforce our determination of the boundary, the conodont *Synclydognathus geminus* also disappears in the upper part of unit N. This conodont is the key conodont in the *Apatognathus scalenus-Cavusgnathus* Assemblage Zone of Rexroad and Collinson (1963) and Collinson et al. (1971) and has its last appearance at or very close to the top of the St. Louis in Illinois, Indiana, and eastern Missouri (Collinson et al. 1971). This last appearance corresponds to our placement of the St. Louis-Ste. Genevieve boundary between units N and O–P (Fig. 37).

Collinson et al. (1954) noted deep fissures extending downward several feet into the top of unit N that were filled with material from unit P. (Unit O is a thin local unit that is not always present.) Similar fissures were also reported to be present at the top of the St. Louis in Ste. Genevieve County, Missouri (Weller and St. Clair 1928) where the upper St. Louis has been truncated and a prominent conglomeratic horizon occurs at the St. Louis-Ste. Genevieve boundary. A comparison of this interval with that in a nearby quarry indicates that unit N is much thicker here, suggesting that some beds may have been eroded away at the top of the St. Louis before the deposition of the algal beds (units O–P). The fissures suggest that subaerial exposure and dissolution from karstification may have occurred at the end of St. Louis deposition. Because of inaccessibility, the fissures noted by Collinson et al. (1954) cannot be seen at this location. The abrupt change from thin-bedded normal marine beds (unit N) to shaly and sandy oncolitic beds of unit P is significant and probably represents the transgressive facies of the lower part of the Ste. Genevieve.

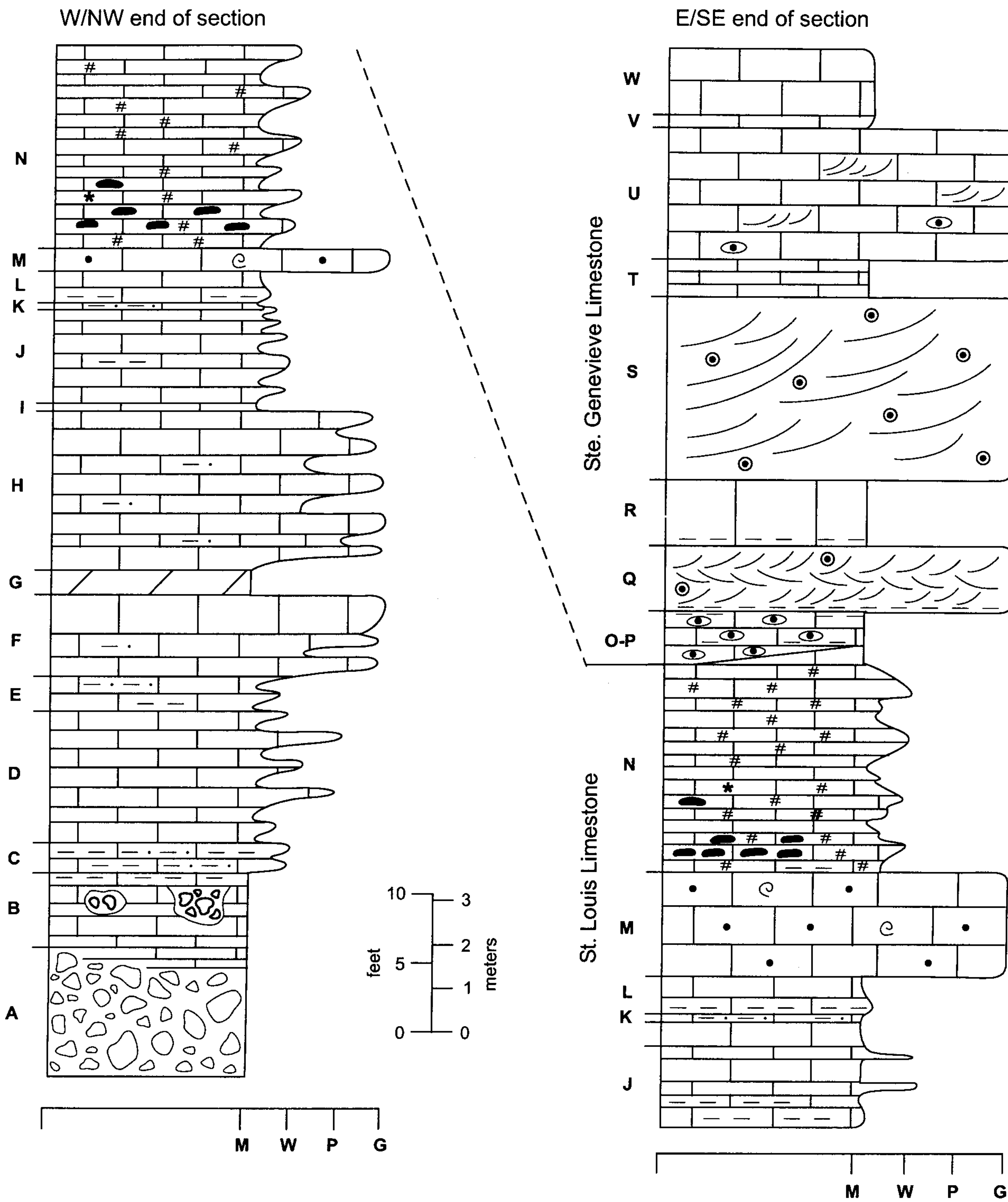


Figure 37 Stratigraphic columns for the northwest and southeast end of the Alton Bluff Section. See Figure 20 for key.

STE. GENEVIEVE LIMESTONE

Beds T, U, and W. Limestone, variable, inaccessible or difficult to access, thin-bedded to slightly cross-bedded, partly algal, some shaly.

Bed S. **"Sandy oolite,"** grainstone, oolitic, cross-bedded, massive.

Bed R. **"White bed,"** lime mudstone to wackestone, cream to light grayish brown, weathers nearly white, thin shale parting at base.

Bed Q. **"Chevron bed,"** limestone, appears oolitic, arenaceous, bimodal cross-beds; basal part of unit is an oncolitic conglomerate; unit thickens toward Mississippi Lime's sand piles.

Bed P. **"Algal conglomerate,"** lime mudstone to wackestone, argillaceous, with numerous algal oncolites ranging in size from a few millimeters up to 30 centimeters in diameter, light brownish gray, often with green tinge; upper 15 centimeters is very shaly with small oncolites, basal surface irregular.

Bed O. **"Little white bed,"** grainstone?, silty, algal, lenticular, erosional base, fills cracks in bed N, not present at southeast end of exposure.

ST. LOUIS LIMESTONE

UPPER ST. LOUIS

Bed N. **"Bryozoan beds and chert marker,"** wackestone to lime mudstone, light grayish brown, very fine-grained, bioclastic, bryozoan-rich particularly in lower part, sporadic chert in lower part, one particular bed near base is considered to represent part of the Lost River Chert Bed, thin bedded, generally 10–20 centimeters, some thinner, lower contact undulatory.

Bed M. **"Lower oolite,"** grainstone, light brownish gray to light gray unweathered, weathers very light gray, peloidal, fine grained, cross-bedded, cross-bed sets range between 1.0-2.5 feet, upper contact undulatory. Collinson et al. (1954, p. 18) described this as a slightly sandy oolite (we did not note any true ooids).

Bed L. **"Two beds,"** lime mudstone with some fine- to coarse-grained bioclastic grainstone, two distinct beds, slight shale parting at base.

Bed K. Limestone, very silty, grading downward to prominant shale break.

Bed J. Lime mudstone with some bioclastic grainstone, slightly silty, thin-bedded, several shale streaks.

Bed I. **"Five-inch bed,"** limestone bed between two distinct shale partings.

Bed H. Lime mudstone to grainstone, slightly silty.

Bed G. **"Dark band,"** dolomite, silty, medium brownish gray, thickness varies from 1 to 24 inches.

Bed F. Lime mudstone with some grainstone, slightly silty.

Bed E. **"Pseudoconcretion bed,"** limestone, silty and shaly with numerous large oval 6-inch to 3-foot silty dolomite pseudoconcretions.

Bed D. Lime mudstone, some wackestone and grainstone, fossiliferous.

Bed C. Wackestone primarily, but variable lithology, greenish gray, shaly, silty, argillaceous, and fossiliferous.

LOWER ST. LOUIS

Bed B. **"Upper breccia,"** lime mudstone with some grainstone, variable in lithology and partially brecciated.

Bed A. **"Main breccia,"** limestone, highly brecciated with angular clasts (some boulder sized) of lime mudstone to grainstone in silty grainstone.

Explanation for Figure 37 Lithologic description of Alton Bluff Section; lettered beds and names in "quotes" were used by Collinson et al. (1954) and are given for comparison purposes. Most of the lithologic information is from Collinson et al. (1954) with updated notes on beds C and M through S from this study.

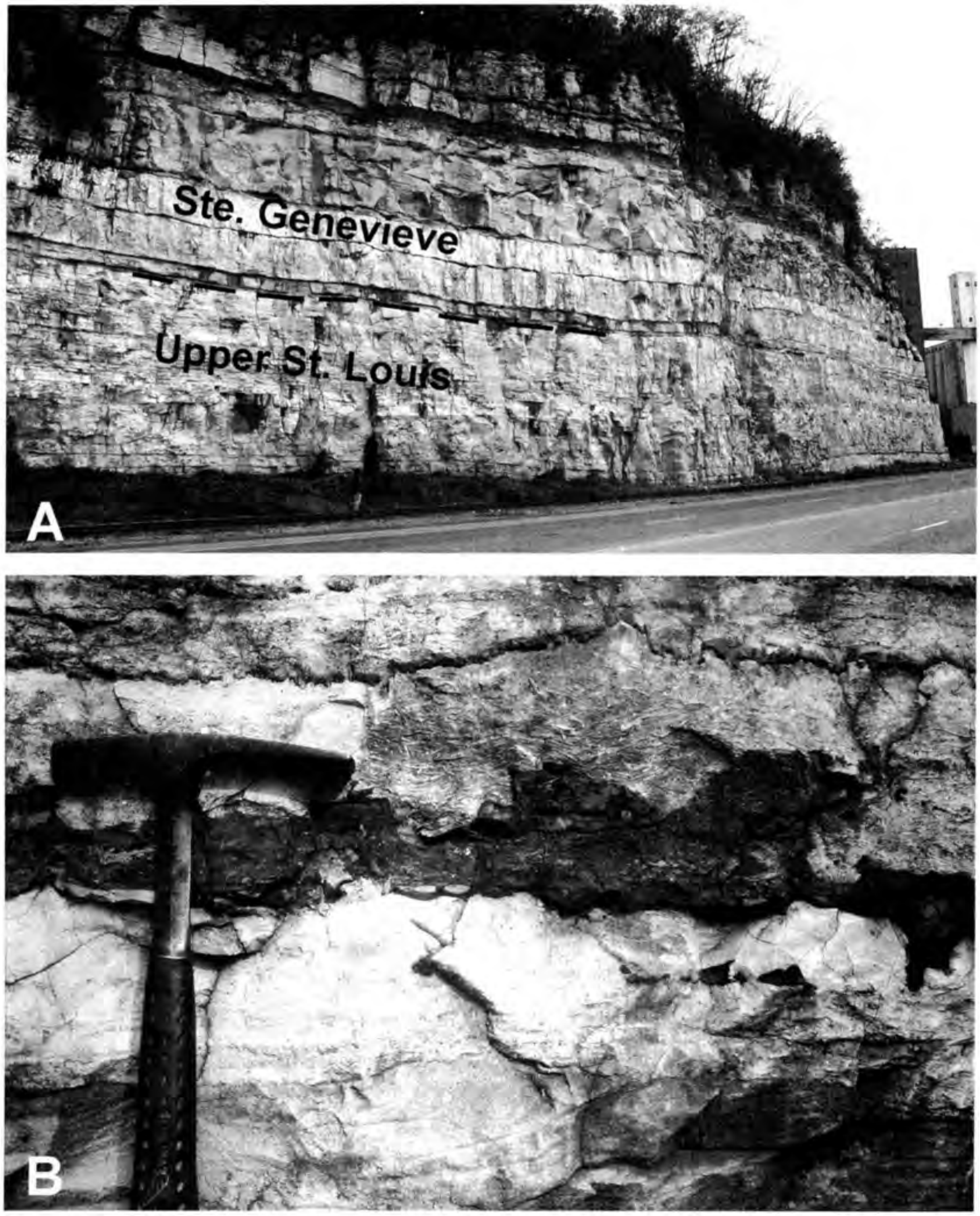


Figure 38 Features of the Alton Bluff Section. **A.** Overall view showing upper St. Louis and Ste. Genevieve Limestones from Beds J through W on the southeast end of section (Fig. 38), person for scale. **B.** Close view showing chert (dark gray) bed in the bryozoan-rich 'Lost River Chert' zone in the upper St. Louis, hammer for scale.

Stop 6: Faulting in the Alton Bluff Section—*Joseph A. Devera and F. Brett Denny*

NW NE NW Sec. 14, NE NW NW Sec. 14, and SW SW Sec. 11, T5N, R10W, additional section present in SE Sec. 10, T5N, R10W; Alton 7.5-minute Quadrangle, Madison Co., Illinois (Fig. 36)

A strike-slip fault zone occurs in an old quarried bluff on the property of the Abbott Machine Company (SW SW Sec. 11, T5N, R10W) on the Mississippi River at Alton, Illinois (Fig. 39). Numerous vertical and undulating vertical fractures occur on the highwall within the St. Louis Limestone and the lower part of the Ste. Genevieve Limestone. The fractures strike N10°E to N60°E. Well-developed horizontal slickensides, mullions, brecciation, and large calcite veins are present on fault surfaces. Offsets of 6 inches to 12 inches are observed on the bedding along these structures. Down-stepping of bedding to the east at a horizontal distance of 200 feet yielded offsets of about 6 feet. Both right-lateral and left-lateral movements were found on the highwall. The largest fault appears to be a right-lateral fault that strikes N10°E. Some of these faults were originally reported in the guidebook by Collinson et al. (1954).

Along the same highwall traversing east, a yellowish crinoidal limestone marker bed "steps down" to the east about 5 feet between three faults over a distance of 40 feet. The dip of the marker bed is 4° to the east with a northeast strike. The first two strike-slip faults also dip to the east about 70°; the third fault is vertical. Farther east of the third fault the marker bed is displaced below the quarry floor. Continuing east along the highwall, more vertical strike-slip faults with mullions, clay gouge, and breccia are common; however, the dip on the beds reverses to the west about 4° and strikes northeast, which is evidence for extension in the small area near the Abbott Machine Company.

Harrison (1993) reported that calcite mineral growth along these faults indicates that the N 45° to 70° E faults have a left-lateral sense of slip, whereas the N5° to 10°E faults show a right-lateral sense of slip. Harrison (1993) suggested that the area along the bluff shows small-scale positive flower structures indicating transpression; however, small areas such as those by the Abbott Machine Company may be local extensional adjustments that look like small-scale negative flower structures.

The faults trending N45° to 55°E in the bluffs southwest of Alton, Illinois, are through-going faults that are also observed in an abandoned quarry one third of a mile to the northeast of the bluffs in the City of Alton. These faults are strike-slip faults that also appear to have a left-lateral sense of slip. These N45° to 55°E faults parallel and are on strike with the St. Charles magnetic anomaly (Harrison 1993).

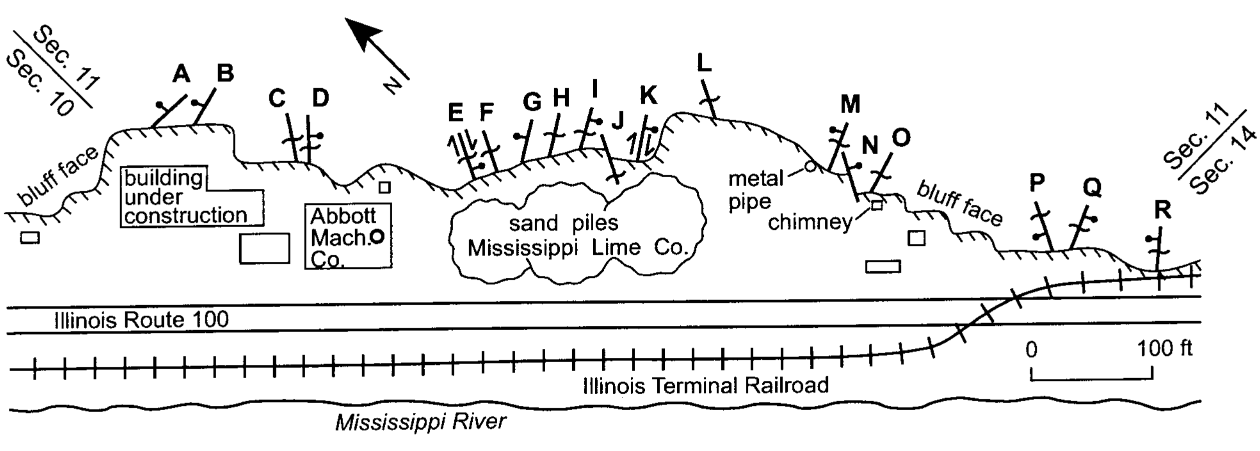


Figure 39 Sketch map of Alton Bluff Section on west side of Alton, Illinois, showing faults in the St. Louis Limestone, Sec. 11, T5N, R10W, Alton 7.5-minute Quadrangle, Madison County, Illinois. Map by W. John Nelson with Joseph A. Devera, October 20, 1997.

Stop 7: Keller Quarry—*Donald G. Mikulic and Joanne Kluessendorf*

NW NW Sec. 14, T6N, R12W; Grafton 7.5-minute Quadrangle, Jersey Co., Illinois (Fig. 40)

Westward from Alton, Silurian rock exposures first appear in the river bluffs at Rice Hollow, the former site of an explosives plant and now the Raging River Water Park. East of Rice Hollow, which is thought to be the site of a poorly exposed fault, the Silurian occurs only below the level of the Mississippi River. To the west, the Silurian forms the lower portion of the river bluffs where it is overlain by Quaternary loess deposits as well as a thick Mississippian and a thin Devonian section. Several long-abandoned quarries occur between Rice Hollow and the Keller Quarry. All are located in Silurian rocks of unit E and the upper part of unit D (Fig. 17). The Keller Quarry is now the site of the Grafton Visitor Center and is the best place to examine local Silurian rocks. **The high quarry walls here are extremely dangerous and should not be approached under any circumstance. The quarry area just west of the visitor center parking lot is private property and should not be entered without the owner's permission.**

The Keller Quarry was the last operating quarry in the Grafton area. The date it opened is unrecorded; however, the site was already being quarried during the 1880s. The Grafton Dolomite Stone Company Quarry was incorporated in 1895 specifically to operate at this site. Around 1919, the C. M. Hanes Stone Quarry Company operated the quarry here. It was purchased by the Keller Construction Company in about 1930. In the 1940s, it was operated by Paul Berg and, later, by the Passelacqua Brothers. From 1956 until 1975, it operated under the name Grafton Quarry. Because it was the most recently operating quarry in the area, it has been a stop on several previous field trips including the Fourth Tri-State Field Conference (Sutton 1936) and a 1947 Illinois State Geological Survey field trip led by G. O. Raasch.

This quarry area exhibits the most complete continuous section of Silurian rocks around Grafton, and displays the only good exposure of the upper strata. The main quarry has a loess deposit 30 feet thick overlying the Middle Devonian Cedar Valley Limestone, the Silurian building-stone beds of unit E, and the upper part of the underlying unit D strata, which were quarried for riprap and crushed stone. The northward-increasing thickness of loess, which was expensive to remove, is one of the reasons the last quarry here closed. The east pit is deeper and, in addition to rock units found in the main quarry, includes all of units D and C and the upper 6 feet (2 meters) of unit B. The road cut, which extends from the visitor center driveway to the entrance to Simms Hollow, exposes the lower portions of unit D, all of unit C, and the top of unit B (the only exposure of the latter is on the highway right-of-way. **Stay out of the private property in Simms Hollow to the north.**

Just west of Simms Hollow is the old Grafton Quarry Company quarry, which was the main source of building-stone produced in Grafton during the late nineteenth century. **This quarry is on private property and should not be entered without the owner's permission. The high quarry walls are extremely dangerous and should not be approached under any circumstance.**

Highway 100 runs across the old Grafton Quarry Company quarry floor here. To the south of the highway is the former location of the docks and loading derricks that are illustrated in the 1872 Grafton Stone & Transportation Company quarry lithograph (Fig. 41). To the north, the old main working face of the quarry can be seen. It is not known when the quarry first opened; however, it was operated as the Grafton Stone Works by Farrington & Loler in the late 1850s. In the early 1870s, the same individuals ran the quarry as part of the Grafton Stone & Transportation Company (G. S. & T Co.). Around 1875, the G. S. & T. Company closed because of financial difficulties, and the Grafton Quarry Company was incorporated to operate the quarry here. The primary owners of this company were E. Meysenburg, J. Black, J. S. Roper, Charles Brainerd, and the Allen family. The Allen family, major landowners around Grafton, actually owned the quarry property. Brainerd was the on-site superintendent, and Black and Roper operated the St. Louis office. This company stayed in business until about 1920. Even though this quarry was the largest in Grafton, there was little activity at the site after World War I.

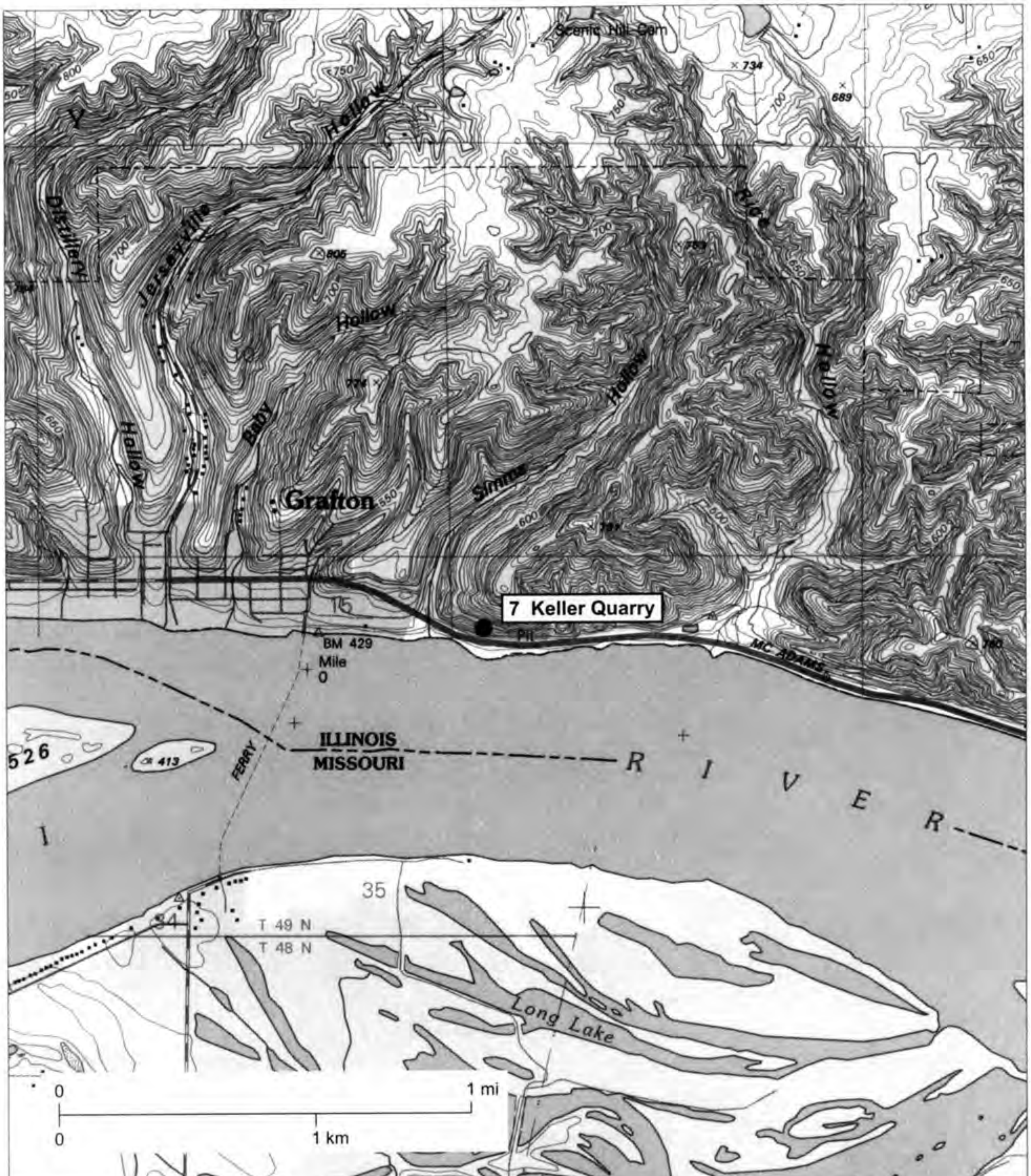


Figure 40 Location map of Keller Quarry (Stop 7). NW NW Sec. 14, T6N, R12W; Grafton 7.5-minute Quadrangle, Jersey Co., Illinois.

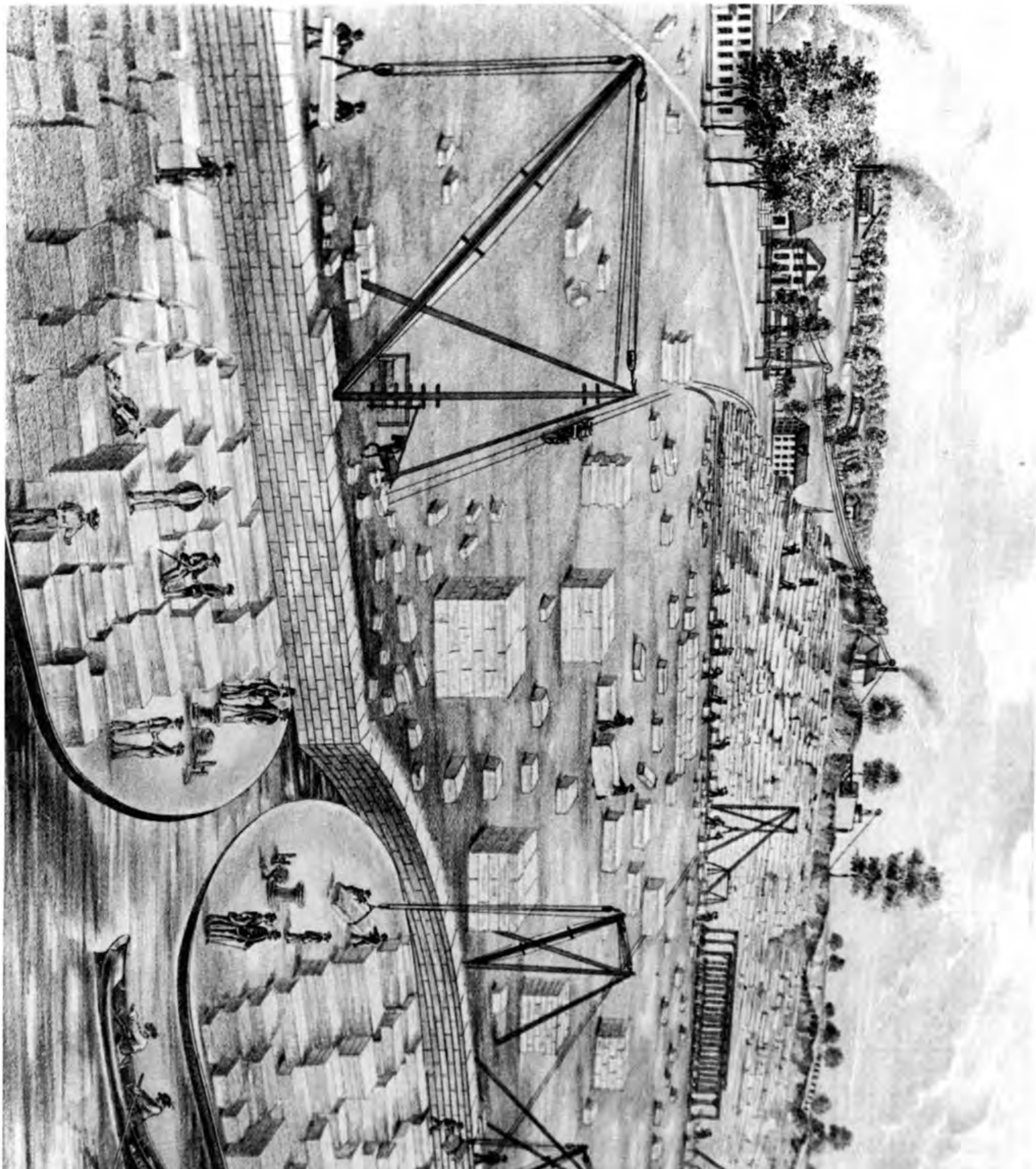


Figure 41 An 1872 lithograph of the Grafton Stone and Transportation Company quarry at Grafton, Illinois.

The old quarry face exposes the principal strata that were quarried for building stone and illustrates some of the problems involved in operations here. As much as ten feet of soft, shaley and sandy Middle Devonian limestone unusable for building stone occurs at the top of the quarry wall. These Devonian rocks probably had been eroded away nearer to the river, where the quarries first started. As the quarries worked into the bluff towards the north, however, they encountered an increasing thickness of these strata, which were waste rock that had to be removed to access the underlying Silurian building stone. In addition, increasingly thick deposits of loess, which also had to be removed, were present above the Devonian strata. The loess was excavated hydraulically at various times, being washed directly into the river. Beneath the Devonian strata are approximately 50 feet of well-bedded Silurian rock that yielded all of the building stone quarried here. Although it has been commonly referred to as the Joliet Formation or Racine Formation by earlier authors, in reality, it is stratigraphically equivalent and lithologically similar to the younger Sugar Run Dolomite of northeastern Illinois. The even texture, hardness, and well-bedded nature of these strata all contributed to their successful use as building stone; however, the thick nature of many of these beds made them especially valuable as foundation stone. The underlying strata of unit D were never quarried here, and the floor of this quarry is noticeably higher than the floor of the Keller Quarry. A rubbly area in the quarry wall near the east edge of Grafton marks a fault zone, which appears to have lateral displacement but little, if any, vertical displacement.

In addition to the main quarry exposures, a number of other important Silurian outcrops occur in and west of Grafton, including Jerseyville Hollow, the School Section, Camden Hollow, and well-known outcrops such as Twin Springs in Pere Marquette State Park.

For interested parties, the following stone structures and outcrops can be seen in Grafton from east to west along Main Street (Highway 100):

- The Charles Brainerd House (c. 1885) at 420 E. Main Street was owned by a former superintendent of the Grafton Quarry Company. It is a large brick house with fine Grafton stone foundation, sills, lintels, and stringline. This house is listed on the National Register of Historic Places.
- The former quarry office of the Grafton Stone & Transportation Company is located on the southeast corner of Main and Cherry Streets. The front and west walls of this building are constructed of very well-dressed or sawed large and thick Grafton-stone blocks of the type that would have been furnished to the St. Louis market as the highest-quality building stone available. Numerous drill marks can be seen in the uppermost course of stone on the west wall. The east wall of the building, which might have abutted another structure, is made of very rough-dressed blocks. This is one of the most historically significant buildings in Grafton because it symbolizes the commercial development of the stone industry here, having served as the office of the Grafton Stone & Transportation Company, the first company to regularly ship Grafton stone to the St. Louis market.
- Local-stone retaining walls are common on the north side of Main Street between Vine and Cherry Streets
- The large local-stone building at the northeast corner of Main and Oak Streets, now housing the Golden Eagle Antiques store, has its original stone front covered with a newer facade. The sides of the building are rough-dressed stone.
- The front of the Grafton-stone building (c.1859) now housing Main Street Antiques is constructed of well-sawed blocks. The east side of the building, which would have abutted another building, is composed of rough, irregularly dressed stone compared with the west side, which faced Oak Street. Foundation blocks below the stringline are also rough-dressed.
- Victorian brick house (229 E. Main Street) with Grafton-stone foundation, steps, sills, and coping beneath the wrought iron fence on the southwest corner of Main and Oak Streets.
- The foundation of the building at 203 E. Main Street is constructed of Grafton stone. A number of internal and external molds of the trilobite *Gravicalymene celebra* can be seen in protected blocks at the back of the building. Many of the building-stone blocks in structures throughout town probably contain trilobite specimens; however, trilobites are difficult to see on weathered surfaces.

- The Slaten-LaMarsh House (25 E. Main Street) at the southwest corner of Main and Vine Streets is a rough-dressed Grafton-stone building (c. 1840) with carved stone steps. It is on the National Register of Historic Places.
- To the northeast, State Highway 3 ascends Jerseyville Hollow, which exposes an essentially continuous section from lower Silurian (Bowling Green Dolomite) up through Mississippian Burlington Limestone. Faulting causes some of the Silurian section to be repeated in the lower part of the hollow. Several old quarries, including the Callahan Quarry, are located in the Silurian rocks in this hollow.
- Remnants of Dr. Dempsey's once-extensive garden fence made of geodes can be seen on the northeast corner of Sycamore and Main Streets. The geodes were weathered out from Mississippian rocks and were collected from stream beds in the area.
- Between Maple Street and Sycamore Street there are several buildings using stone in their construction. A large frame house (c. 1895) at 119 W. Main Street, which is on the National Register, has a rough-dressed local-stone foundation. The frame house at 109 W. Main Street has a sawed-stone foundation and porch. A stone shed is located on the north side of the street.
- The Purdon Saltbox House (c. 1836) at 120 W. Main Street, just east of Maple Street, is constructed of very rough-dressed Grafton-stone blocks with the exception of the sills and lintels. This building is listed on the National Register of Historic Places.
- Just east and south of the Piasa Winery, at the foot of Maple Street, is the New Wharf (c. 1846), an old Grafton-stone pier along the river, which is listed on the National Register of Historic Places. The sidewalk just east of the winery retains some of its old stone slabs. In the late nineteenth century, undoubtedly, most of the sidewalks in Grafton were made of large planed slabs of Grafton stone. Most slabs have since been removed and replaced with concrete, a typical modern alteration of which most people are unaware.
- Piasa Winery (c. 1840) is located in an old stone cottage at 211 W. Main Street on the south side of the road. This building is made of rough-dressed Grafton stone with better-dressed quoins, sills, and lintels. Although the blocks are better matched than at St. Patrick's Church, a large amount of mortar was used.
- Grafton School is on the north side of Main Street at Mulberry Street. The original Grafton-stone school building has been razed, but the old stone retaining wall remains. Numerous local-stone retaining walls continue eastward along the north side of Main Street. Nearly all of the stone buildings indicated on the 1894 Sanborn Insurance Atlas maps of Grafton, except for the school, are still standing.
- Along the sidewalk on the north side of Main Street is a Silurian outcrop about 30 feet high with strata dipping slightly to the east-southeast. At the west end of the outcrop, the contact between units D and C is exposed; the east end of the outcrop is probably unit A. This may be a large slump block.
- St. Patrick's Church (c. 1871) to the north on Evans Street was the church of the Irish quarry workers and is constructed of Grafton stone. The quoins, stringline, window sills, and surrounds are composed of sawed stone, whereas the rest of the building is made of rough-dressed blocks showing considerable variation in size and shape, suggesting a cheaper grade of stone. A large amount of mortar was needed because the stone blocks of widely varying size did not fit together well.
- In passing Mason Hollow Road, note the stone cottage to the north on Springfield Street (a.k.a. Mason Hollow Road). This is the Paris Mason house (c. 1840), built of rough-dressed blocks of Grafton stone that were typical of that early period. The cottage is on the National Register of Historic Places.
- An old and unused stone bridge over Daggett Hollow can be seen in the distance to the north.
- City of Grafton Waterworks is on south at the west edge of Grafton. Waterworks building was erected of Grafton stone in 1936 in masonry style typical of that period.
- The Illinois Youth Detention Center located in Camden Hollow is also built of Grafton stone. The beautiful stone buildings at this site were built from 1922–1932 by Harry Ferguson at the

then Glencliffe Jersey Farm, a showplace dairy farm. Ferguson willed this farm to the State of Illinois upon his death in 1943, and, in 1961, it became the Illinois Youth Detention Center. Farther up, Camden Hollow is one of the best exposures of the Ordovician/Silurian contact in the Grafton area.

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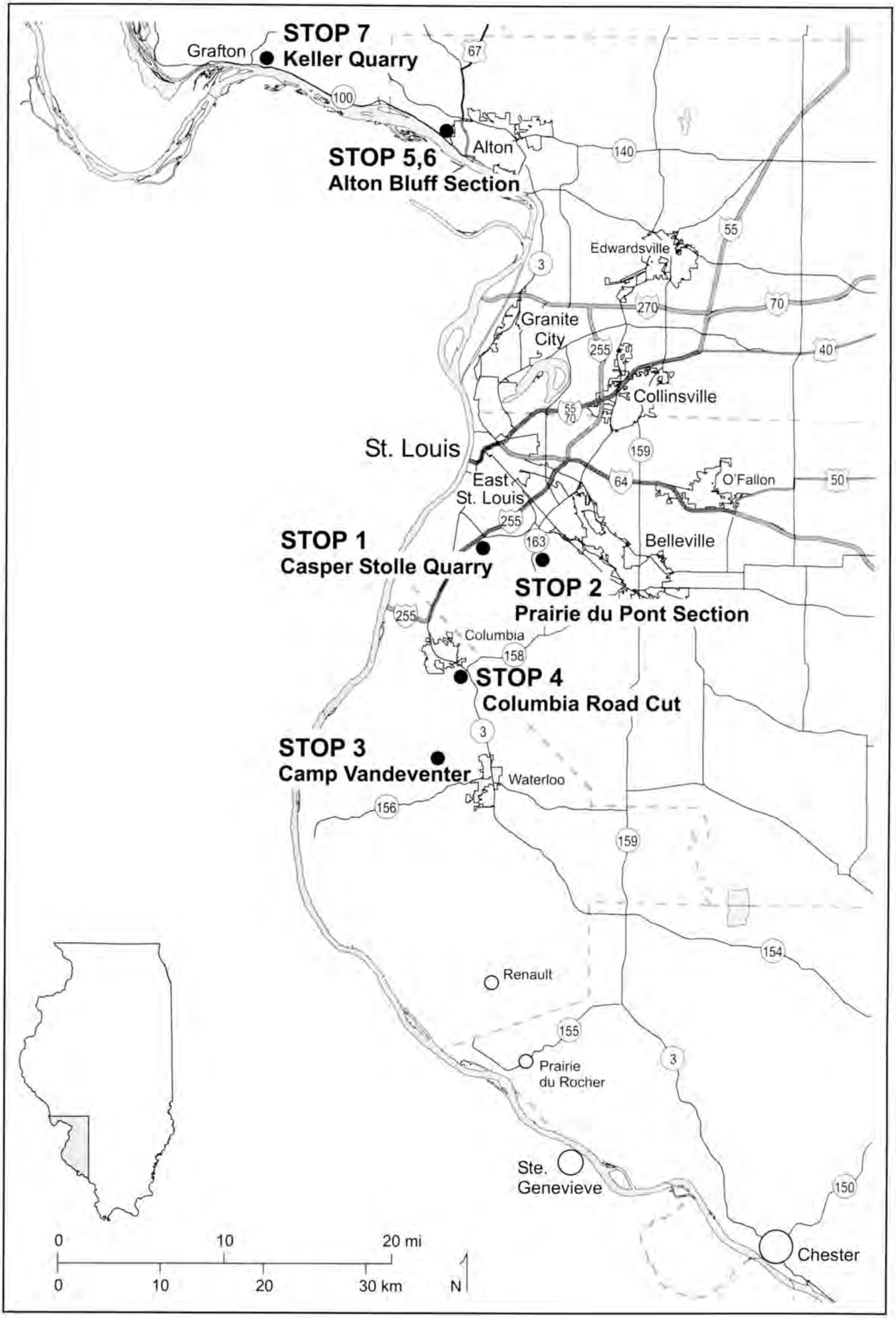
STOP 7
Keller Quarry
Grafton
67
100
Alton
140
STOP 5,6
Alton Bluff Section
55
Edwardsville
3
270
70
Granite City
255
40
Collinsville
55 70
St. Louis
159
East St. Louis
64
O'Fallon
50
255
163
Belleville
STOP 1
Casper Stolle Quarry
STOP 2
Prairie du Pont Section
255
Columbia
158
STOP 4
Columbia Road Cut
3
STOP 3
Camp Vandeventer
Waterloo
156
159
154
Renault
155
Prairie du Rocher
3
Ste. Genevieve
150
Chester
0
10
20 mi
0
10
20
30 km
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