THE SANDWICH FAULT ZONE OF NORTHERN ILLINOIS

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COVER PHOTO: Faulted and shattered Silurian dolomite in the Meyer Material Company quarry (Vick's Pit) located within the Sandwich Fault Zone about six miles southwest of Joliet, Will County, Illinois. A major fault with approximately 100 feet of displacement is marked by the white line. Rocks of the Wilhelmi Formation on the left are upthrown in juxtaposition with the Joliet Formation on the right. Numerous, small high-angle faults and joints can be seen in the highwall. The faulted Silurian dolomite is truncated to a flat surface and is covered by approximately 20 feet of the Wisconsinan Yorkville Till Member.

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ABSTRACT

The Sandwich Fault Zone extends northwesterly from near Manhattan, Will County, to near Oregon, Ogle County, a distance of about 85 miles. Drilling samples from exploratory borings and water wells, drillers' logs, geophysical logs, refraction seismography, earth resistivity profiles, and outcrop studies indicate that the fault zone is about one-half to two miles wide and is upthrown to the south throughout most of its extent. The fault zone has a maximum cumulative displacement of about 800 feet at its midpoint in southeastern De Kalb County. At the eastern end, in Will County, the fault zone is downthrown to the south with a total displacement of about 150 feet.

High-angle faults that commonly bound small grabens and horsts characterize the Sandwich Fault Zone. The Ashton Arch, Oregon Anticline, and many small flexures and faults are closely associated with the fault zone and appear to be genetically related to it. The faulting is post-Niagaran (middle Silurian), pre-Illinoian (Pleistocene) in age. Geologic relationships suggest that the major movements were contemporaneous with the deformation of the La Salle Anticlinal Belt in late Paleozoic time.

INTRODUCTION

Location and purpose of study

The Sandwich Fault Zone is located in the highly populated northern part of Illinois where knowledge of the bedrock geology has many practical applications in land-use planning. An understanding of the fault zone and associated geologic structures is particularly important in (1) evaluating the potential for underground disposal of waste materials and for underground storage of gas and liquid petroleum products, (2) determining the suitability of sites for construction of major buildings such as nuclear power plants, and (3) locating water and mineral resources.

The purpose of this investigation is to determine the extent, magnitude, age, and nature of faulting in the Sandwich Fault Zone. The area of detailed study includes the fault zone and a 10- to 20-mile-wide strip on either side of it (fig. 1). Drilling samples from exploratory borings and water wells, drillers' logs, geophysical logs, refraction seismography, earth resistivity profiles, and outcrops were utilized in this study. All information currently available was used to describe in detail the areal geology and structural configuration along the fault zone.

The Sandwich Fault Zone is a narrow belt of high-angle faults that commonly trends northwestward about 85 miles from near Manhattan, Will County, to near Oregon, Ogle County. The fault zone is generally 1/2 to 2 miles wide and has a maximum cumulative displacement of about 800 feet at its midpoint in southeastern De Kalb County. This prominent geologic feature has had a pronounced effect on the bedrock geology of northern Illinois.

Previous studies

The earliest mention of a structural anomaly in the area of the Sandwich Fault Zone was made by Bannister (1870, p. 138 and 144-146) in a study of outcrops along the Fox River in Kendall County. He noted the unusual occurrence and relations of the St. Peter Sandstone and the Trenton (Platteville and Galena) rocks in this area and described the anomaly as a breached anticline in which the St. Peter Sandstone was exposed along the axis.

Cady (1920, p. 90) studied the geologic structures in the area of the Sandwich Fault Zone and defined two separate yet essentially continuous anticlines, the "Ogle, Lee, and La Salle Counties anticline" and the "Morris-Kankakee anticline." The two anticlines were shown (Cady, 1920, p. 88, fig. 8) generally to parallel the Sandwich Fault Zone as it is now mapped, but both were positioned several miles south of the fault zone.

Pirtle (1932, p. 147 and 149) first applied the term Kankakee Arch to the structure and described it as connecting the Wisconsin and Cincinnati Arches. Ekblaw (1938) also used the term Kankakee Arch. He observed that the subsurface data northeast of Oregon showed all

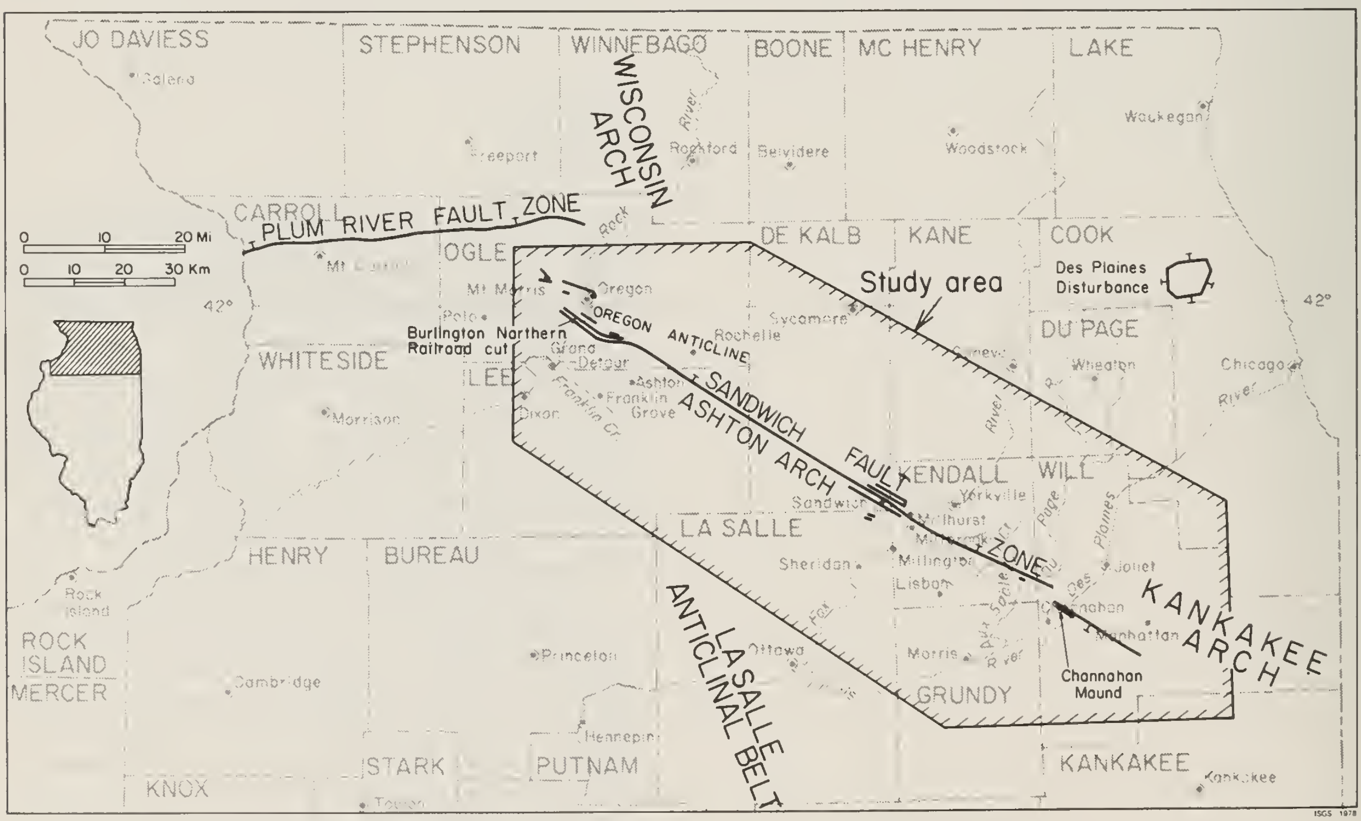

Figure 1. Prominent structural features and area of study.

of the Prairie du Chien (lower Ordovician) and the upper strata of the Cambrian to be missing, although southwest of Oregon a complete sequence of strata was present. This was interpreted as representing post-Cambrian, pre-St. Peter folding and erosion. His map depicted the axis of the Kankakee Arch at nearly the same location as the Sandwich Fault Zone as it is now mapped. Ekblaw extended the axis to the southeast with dashed lines suggesting a possible continuation with the Cincinnati Arch, as was shown by Pirtle (1932, p. 147).

Willman and Payne (1942, p. 186) first described the presence of faulting in the area on the basis of subsurface studies of L. E. Workman and exposures along the Fox River Valley. They applied the name Sandwich Fault in reference to Sandwich, De Kalb County, where faulting was first suspected. Wells only 1/8 mile apart showed displacements of about 180 feet. Other wells with greater spacing showed displacements of up to 500 feet. Willman and Payne recognized that displacements along the fault zone diminished eastward in eastern Kendall County. They suggested that a fault to the east, near Millsdale in Will County, was probably a continuation of the Sandwich Fault. Willman and Templeton (1951, p. 123) recognized the compound nature of faulting and named the structure the Sandwich Fault Zone. Willman and others (1967) updated the interpretation of the extent of faulting and the areal geology.

GEOLOGIC SETTING

The Sandwich Fault Zone is located in a structurally complex area that is near the terminations of three major positive features—the Wisconsin Arch, the Kankakee Arch, and the La Salle Anticlinal Belt (fig. 1). In the northeastern part of the area, the Paleozoic strata dip eastward into the Michigan Basin; in the southwestern part, the strata dip southward into the Illinois Basin. If extended northwestward, the Sandwich Fault Zone would intersect the Plum River Fault Zone (Kolata and Buschbach, 1976). No evidence was found during our study, however, to indicate that the two fault zones are connected.

The many bedrock formations present in the area (figs. 2 and 3) range in age from Cambrian to Silurian and consist of dolomite, limestone, sandstone, and shale, all truncated to a surface of low relief. Pennsylvanian sandstones and shales are present as scattered outliers. Pennsylvanian strata apparently covered the entire area but were largely eroded during post-Pennsylvanian times.

Unconsolidated surficial deposits of glacial drift, loess, and alluvium overlie the bedrock. These deposits are thin at the east and west ends of the fault zone, but they are as much as 500 feet thick in buried river valleys in De Kalb County (Piskin and Bergstrom, 1975, plates 1 and 2). Low relief characterizes the topography of the Sandwich Fault Zone.

STRATIGRAPHY AND AREAL GEOLOGY

Bedrock within the area consists entirely of Paleozoic rocks; Cambrian, Ordovician, and Silurian strata have a combined maximum thickness of approximately 4,000 feet. A few isolated patches of Pennsylvanian strata overlie rocks that range in age from Champlainian (middle Ordovician) through Silurian. The main body of Pennsylvanian strata within the Illinois Basin, however, pinches out along an erosional edge in the southern part of the study area. The Paleozoic rocks rest unconformably on a basement of Precambrian crystalline rocks that are mostly granite and are covered by as much as 500 feet of Pleistocene glacial drift, loess, and alluvium. A generalized stratigraphic section of the rocks and surficial deposits in the study area is shown in figure 3. The stratigraphic nomenclature used here conforms to Willman et al. (1975).

The areal distribution of the rock formations is shown in figure 2. Although numerous formational and subformational units are recognized in these strata, the geologic map shows only the following divisions: the Cambrian System; four rock units in the Ordovician System (the Prairie du Chien Group, the Ancell Group, the combined Platteville and Galena Groups, and the Maquoketa Group); the Silurian System; and the Pennsylvanian System.

The distribution of the bedrock units (fig. 2) is mainly the result of truncation of the Ashton Arch south of the Sandwich Fault Zone and of the Wisconsin Arch that extends into northern Illinois. Platteville and Galena strata occur at the bedrock surface in a broad area near the axis of the Wisconsin Arch and are covered by successively younger strata to the east and west. The oldest rocks at the bedrock surface belong to the Cambrian Franconia Formation and occur on the truncated upthrown side of the Sandwich Fault Zone. Successively younger strata occur to the southwest.

Several valleys in the bedrock surface are entrenched as much as 500 feet below the gently undulant surface of the divides. Two of the most prominent valleys, the Rock and Troy Bedrock Valleys, cut through the Platteville and Galena into the Ancell Group north of the Sandwich Fault Zone, intercept the fault zone at right angles, and cut through Prairie du Chien strata to Cambrian rocks on the south side of the fault zone. For the most part the valleys have been filled by glacial drift and are not reflected in the present topography.

Cambrian System

Cambrian rocks in the area are all assigned to the Croixan Series (late Cambrian); they include the Mt. Simon Sandstone (oldest), the Eau Claire Formation, the Ironton-Galesville Sandstone and the Franconia Formation of the Potsdam Sandstone Megagroup, and the Potosi Dolomite and Eminence Formation of the Knox Dolomite Megagroup.

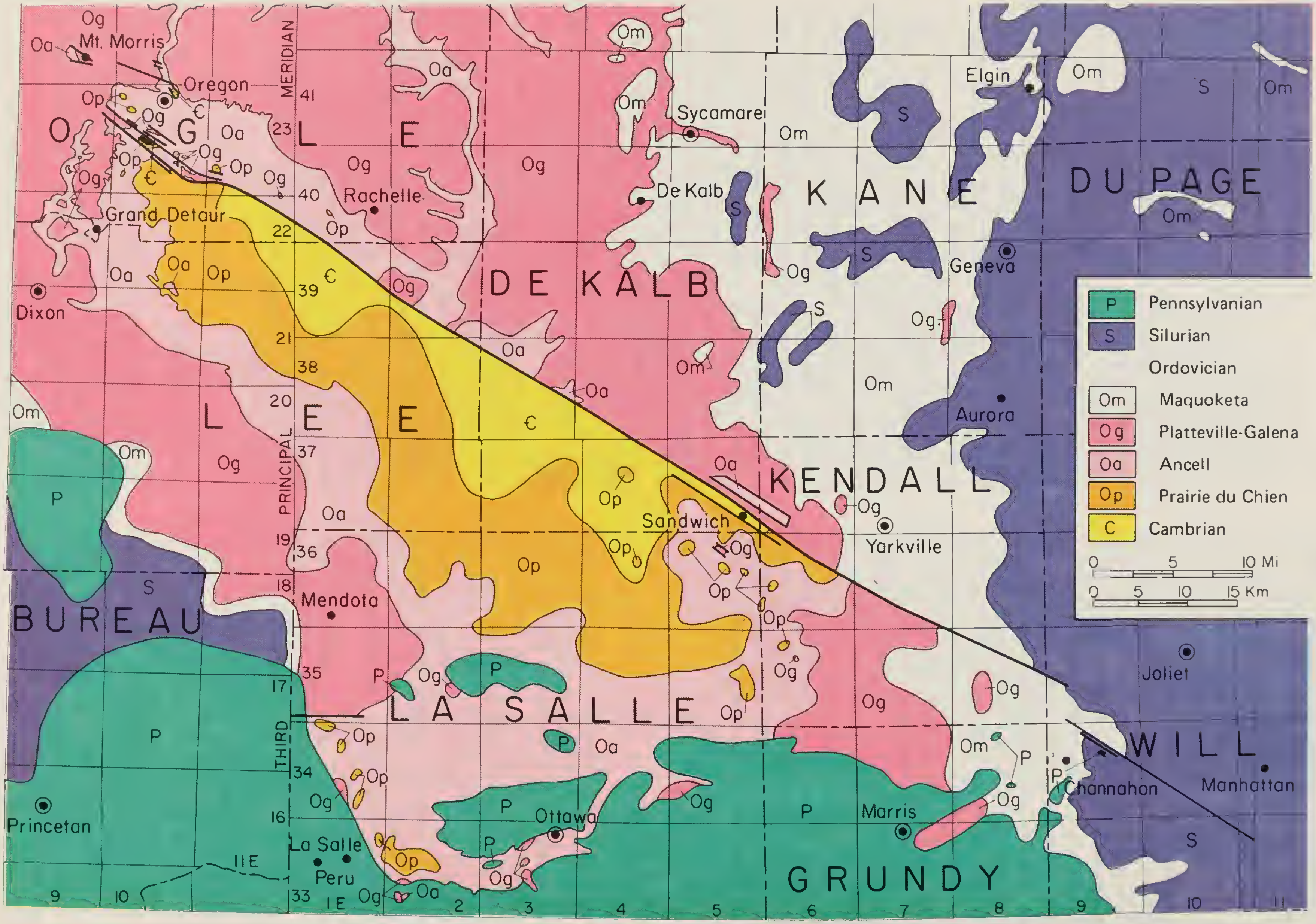

Figure 2. Geologic map of Sandwich Fault Zone and adjacent areas (modified from Willman and others, 1967). Revised geology is confined to area 10 miles on either side of fault zone.

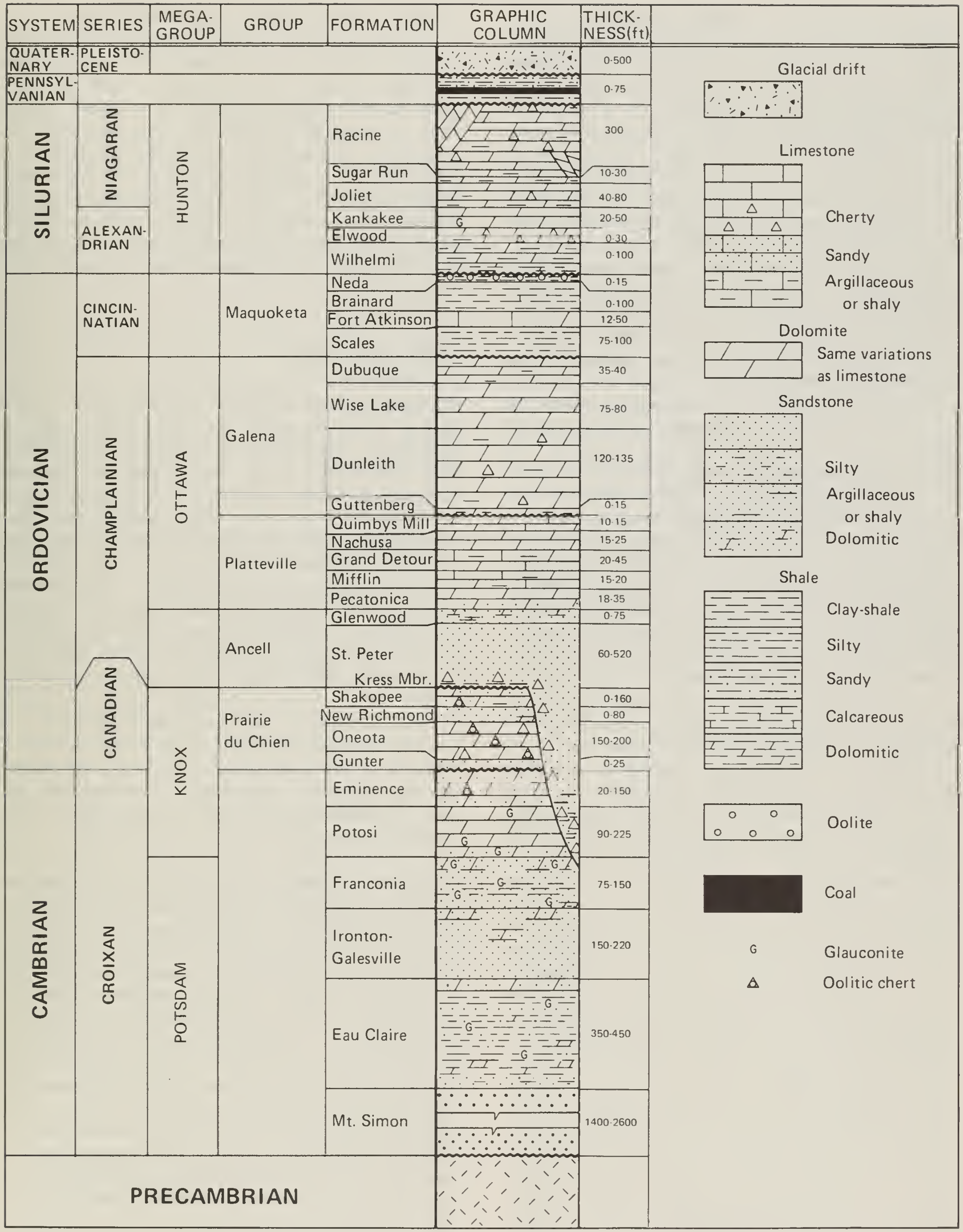

Figure 3. Generalized stratigraphic section in the area of the Sandwich Fault Zone.

The strata consist chiefly of sandstone, dolomite, siltstone, and shale. The contacts between the Cambrian formations are generally transitional; there appears to be no major break in the depositional sequence of the strata (Buschbach, 1964, p. 65-66). The formations can usually be differentiated in the subsurface when adequate drilling samples or geophysical logs are available. The tops of the Franconia, Ironton-Galesville, and Eau Claire are the most easily recognized and the most reliable structural datum planes in the subsurface. Formations below the Franconia are not known to be exposed in Illinois.

The Mt. Simon Sandstone is mostly white to pink, coarse-grained, poorly sorted sandstone that unconformably overlies the Precambrian basement. The thickness of the Mt. Simon ranges from about 1,400 feet in the northwestern part of the study area to more than 2,500 feet in Kendall and easternmost La Salle Counties.

The Eau Claire Formation conformably overlies the Mt. Simon and consists of fine-grained and commonly fossiliferous sandstone, siltstone, shale, and dolomite. The Eau Claire is 350 to 450 feet thick in the area.

The Galesville Sandstone, which overlies the Eau Claire, is a fine-grained, well-sorted, clean sandstone that is generally free from glauconite, shale, and carbonate cement. The overlying Ironton Sandstone is a medium-grained, moderately sorted, partly dolomitic sandstone. When the distinction of the two sandstones is not practical or necessary, they are combined as one unit, the Ironton-Galesville Sandstone. The two sandstones have a combined thickness of 150 to 220 feet in the area.

The Franconia Formation, above the Ironton, consists of fine-grained, dolomitic sandstones characterized by the abundance of scattered fine grains of glauconite and thin beds of green or red shale. The Franconia is from 75 to 150 feet thick in the area; the thicker sections are to the south. Only two exposures of the Franconia Formation have been reported in Illinois. One exposure is in a small abandoned quarry on a hill in the northeast part of Oregon in the S½NE¼, elongate Sec. 3, T. 23 N., R. 10 E., Ogle County (Bevan, 1935), and is largely overgrown. The anomalously high elevation of the Franconia at this location several miles north of the Sandwich Fault Zone appears to be related to local faulting with considerable vertical displacement. The second exposure, 18½ feet of flat-lying beds of Franconia, is in a borrow pit along the north side of the East-West Tollway, Illinois Highway 5, in NW NE Sec. 7, T. 39 N., R. 1 E., Lee County.

The Potosi Dolomite, overlying the Franconia, consists of fine-grained, light brown to light gray dolomite that characteristically contains drusy quartz, a trace of glauconite at the top, and some fine sand and glauconite near the base. The thickness of the Potosi is about 130 feet in the area of study; extremes range from 90 to 225 feet. The Potosi is exposed at several localities near Rochelle, Ashton, and Oregon (Willman and Templeton, 1951, p. 113-114).

The Eminence Formation overlies the Potosi Dolomite and is the uppermost Cambrian Formation in the area. It is light-colored, fine- to medium-grained dolomite that commonly contains sand and oolitic chert. The Eminence grades northwestward into the Jordan Sandstone just beyond the study area. The thickness of the formation ranges from less than 50 feet over the Ashton Arch to about 150 feet in western Will County. The Eminence is exposed in the lower beds of the Stoneridge Limestone Company quarry, located six miles south of Rochelle in NW Sec. 25 and NE Sec. 26, T. 39 N., R. 1 E., Lee County. No other outcrops of Eminence have been reported in Illinois.

Ordovician System

The Canadian Prairie du Chien Group (oldest), the Champlainian Ancell, Platteville, and Galena Groups, and the Cincinnatian Maquoketa Group compose the Ordovician rocks in the area. The Prairie du Chien Group composes the upper part of the Knox Dolomite Megagroup, and the Platteville and Galena Groups compose the Ottawa Megagroup. The Ottawa locally includes the Daysville Dolomite Member of the Glenwood Formation, Ancell Group.

The Ordovician rocks consist mainly of limestone and dolomite, but sandstone and shale characterize some parts of the sequence. Within the area the Ordovician is differentiated into 20 formations and 43 members (Templeton and Willman, 1963; Willman et al., 1975; Willman and Kolata, 1978). These units can be readily identified in outcrops, but in some cases, particularly the limestone and dolomite sequences, the divisions are difficult to define in subsurface samples and geophysical logs. Formational contacts between clastic and carbonate units proved to be the most reliable and easily recognized contacts in subsurface samples and logs.

Prairie du Chien Group. The Prairie du Chien Group consists of cherty dolomite and interbedded sandstone, ranging from a featheredge to about 400 feet thick within the study area. The group overlies the Cambrian Eminence Formation and is overlain with marked unconformity by the St. Peter Sandstone. Uplift to the north and a period of solution and erosion after Prairie du Chien deposition produced a very irregular, karstic surface with several hundred feet of local relief. The Prairie du Chien appears to have formed a north-facing escarpment just south of 42° N. latitude (Buschbach, 1961, p. 87). North of the escarpment the group is completely truncated by the St. Peter Sandstone or is present only in scattered outliers. The Prairie du Chien is generally present south of the escarpment, and it thickens southward, chiefly by addition of younger beds at its top.

The Prairie du Chien Group has been removed from a large area on the south or upthrown side of the fault zone, mainly by post-Mississippian erosion. Outcrops are confined mostly to the Fox and Rock River Valleys.

Four formations recognized within the area are: Gunter Sandstone (at the base), Oneota Dolomite, New Richmond Sandstone, and Shakopee Dolomite.

Consisting of fine- to medium-grained, moderately well-sorted, dolomitic sandstone, the Gunter Sandstone overlies the Cambrian Eminence Dolomite and underlies the Oneota Dolomite. The Gunter is patchy in distribution and has been observed only in a few subsurface samples from Will and Grundy Counties where it is as much as 25 feet thick.

The Oneota Dolomite is a relatively pure, typically coarse-grained, light gray, cherty (usually intricately branched rather than nodular) dolomite that ranges from about 150 feet thick in Ogle County to about 200 feet in western Will County. It commonly contains large hemispherical algal structures. The Oneota overlies the Eminence Dolomite throughout most of the area except where it overlies scattered patches of Gunter Sandstone. The Oneota underlies the New Richmond Sandstone everywhere in the area except in parts of Grundy and Will Counties where the sandstone is absent and the overlying Shakopee Dolomite rests directly on the Oneota. The top of the Oneota is generally a sharp contact that is locally a useful horizon for mapping structure. The Oneota is exposed in outcrops adjacent to the fault zone along the Fox River in Kendall County and in several outcrops located between Ashton and Oregon in Lee and Ogle Counties (Willman and Templeton, 1951, p. 117).

The New Richmond consists of moderately sorted, medium-grained, well-rounded, dolomitic sandstone; it overlies the Oneota Dolomite and underlies the Shakopee Dolomite. Within the study area in southeastern Kendall and Will Counties, the New Richmond is about 80 feet thick: it thins westward to 25 feet in southern Ogle County and thins abruptly eastward to a featheredge at the western border of Will County. The New Richmond crops out in the bluffs of the Fox River west of Sheridan in La Salle County, along Franklin Creek in Lee County, and in several poor exposures in or near the fault zone in southern Ogle County (Willman and Templeton, 1951, p. 119).

Difficulties exist in differentiating the New Richmond Sandstone from the St. Peter Sandstone, especially where the Shakopee Dolomite is missing and the St. Peter rests on the New Richmond or Oneota. In the area south of Sandwich, De Kalb Countv, in T. 35 and 36 N., R. 5 and 6 E. of La Salle and Kendall Counties, many of the water wells, a major source of subsurface information in this area, encounter sandstone at the bedrock surface but are not drilled deep enough to determine whether the bedrock belongs to the St. Peter or New Richmond, or both. The New Richmond has a higher proportion of heavy minerals, but this is difficult or impossible to determine from water well samples, drillers' logs, or geophysical logs.

The Shakopee Dolomite is a heterogeneous unit consisting mainly of fine- to medium-grained, pure to argillaceous dolomite containing thin beds of medium-grained, cross-bedded sandstone, greenish gray shale, buff siltstone, and bands and nodules of oolitic chert. It commonly contains irregular algal structures. The top of the Shakopee is a major erosional unconformity with considerable local relief. Consequently, the thickness varies greatly throughout the area, ranging from a featheredge to a maximum of about 160 feet. The Shakopee overlies the New Richmond throughout most of the area except in parts of Grundy and Will Counties where the New Richmond is absent and the Shakopee rests directly on the Oneota. The Shakopee is overlain by the St. Peter Sandstone. The Shakopee crops out on the west side of Rock River and in numerous outcrops in southern Ogle County, northern Lee County, and along the Fox River in La Salle and Kendall Counties (Willman and Payne, 1943, p. 534-535; Willman and Templeton, 1951, p. 120-121).

Ancell Group. The Ancell Group, predominantly a clastic unit, comprises the St. Peter Sandstone and the Glenwood Formation. It unconformably overlies the cherty dolomite and sandstone units of the Prairie du Chien Group and underlies the dolomite of the Pecatonica Formation of the Platteville Group, from which it is separated by a widespread unconformity of low relief. The Ancell is well exposed in the bluffs of the Rock River Valley and tributaries from Oregon to Grand Detour and is intermittently exposed south of the fault zone along the Fox River in Kendall County.

The St. Peter is a pure, generally white, fine- to medium-grained, sub-rounded to rounded, well sorted, friable sandstone. Generally 150 to 250 feet thick in the area, it varies, however, from as little as 60 feet thick in a boring at Mt. Morris, Ogle County, to as much as 520 feet in a boring at Joliet, Will County. Variations in thickness are due mainly to the considerable relief of the pre-St. Peter surface. Locally the basal part of the St. Peter (Kress Member) consists of chert conglomerate and occasionally thin beds of red sandy clay and green shale—probably a residue from the solution of the underlying cherty dolomite and sandstone that was concentrated in depressions on the pre-St. Peter surface (Buschbach, 1964, p. 51).

The Glenwood Formation overlies the St. Peter Sandstone and underlies the limestone and dolomite of the Platteville Group. A highly variable unit consisting of poorly sorted sandstone, silty dolomite, and green shale, it is generally 10 to 20 feet thick but may be as much as 75 feet locally. The Glenwood is characterized by abrupt lateral changes in lithology; in some places it is absent or unrecognizable. There is generally a decrease in the green shale from the northwest to the southeast. The Glenwood is exposed in a few places along the fault zone in the bluffs on the west side of Rock River, south of Oregon, Ogle County.

Because it is a surface of relatively low relief, the top of the Ancell is a useful structural horizon, which can be recognized with a high degree of confidence throughout the area both in outcrop and in the subsurface.

Platteville and Galena Groups. The Platteville and Galena Groups consist primarily of limestone and dolomite with a combined thickness of approximately 360 feet. They overlie the sandstone, the shale, and the silty dolomite of the Ancell Group and underlie the Maquoketa Shale Group. Platteville and Galena strata occur at the bedrock surface in and adjacent to the fault zone. They are well exposed in many outcrops between Oregon and Rochelle, in the bluffs west of Rock River between Oregon and Grand Detour, and in several isolated outcrops in Kendall County.

The Platteville and Galena strata are characterized by subtle vertical and horizontal variations in lithology. They are subdivided into a number of widespread units that are based mainly on the relative amount of disseminated clay and silt, small variations of which affect the physical appearance of the strata. Recognition of the differences in lithology of the rocks and familiarity with the criteria that distinguish the units are best obtained by studying outcrops.

The Platteville Group consists mainly of gray to brown, very fine- to fine-grained dolomite except locally where it consists of blue-gray, lithographic, partly dolomite-mottled limestone and, in some parts of the sequence, abundant white to gray chert. The Platteville thickens southward from about 110 feet in Ogle County to about 145 feet in Grundy County. It overlies the predominantly clastic rocks of the Ancell and underlies the coarser grained rocks of the Galena. In subsurface the top of the Platteville is a good structural horizon because it is easily recognized as an abrupt change to finer grained rock that is generally darker in color than the overlying Galena.

The Platteville is differentiated into five formations (fig. 3): Pecatonica (oldest), Mifflin, Grand Detour, Nachusa, and Quimbys Mill. These units are further subdivided into a number of members and beds that are locally distinct in outcrop but are seldom recognized in subsurface. All five formations occur at the bedrock surface within the fault zone and are particularly well exposed in outcrops in southern Ogle County.

The Pecatonica Formation consists of 18 to 35 feet of brown, fine- to medium-grained, relatively pure, locally cherty dolomite or limestone. It rests on the predominantly clastic rocks of the Glenwood Formation, or where the Glenwood is missing, it rests on the St. Peter Sandstone. It underlies the Mifflin Formation. A ferruginous corrosion surface is prominent at the top throughout the area.

The Mifflin Formation is characterized by 15 to 20 feet of gray to light tan, thin-bedded, very fine-grained limestone or fine-grained dolomite with gray to green shaly partings. The Mifflin is generally much more argillaceous than the underlying Pecatonica or overlying Grand Detour Formations.

The Grand Detour Formation consists of 20 to 45 feet of fine- to medium-grained, medium-bedded, locally cherty dolomite or dolomite-mottled limestone. It is relatively pure at the base but becomes argillaceous near the top.

The Nachusa Formation overlies the Grand Detour. It consists of 15 to 25 feet of locally cherty, thick-bedded, pure dolomite or limestone.

The Quimbys Mill Formation, which is the uppermost formation of the Platteville Group, consists of 10 to 15 feet of brown, fine-grained, mostly thin-bedded, slightly argillaceous dolomite or limestone. It overlies the relatively pure rocks of the Nachusa Formation and underlies the coarser grained dolomite and limestone of the Galena Group. A ferruginous corrosion surface is commonly present at the top.

The Galena Group consists of medium-grained, pure, light gray to buff dolomite except in the southern part of Kendall County and southward where the unit changes to limestone characterized by thick beds of calcarenite. Throughout most of the area, the uppermost part of the Galena has been eroded; consequently, the thickness of the unit is variable. Where the full section is present, the Galena ranges from 220 feet thick in Will and Grundy Counties to 250 feet in Ogle County.

The top of the Galena is a widespread, ferruginous, pitted surface that locally has abundant phosphatic pellets and a depauperate molluscan fauna concentrated on the surface and in the basal 10 to 12 inches of the overlying Maquoketa Shale. The top is readily identified in outcrop and subsurface. Because the Galena shows little variation in thickness throughout the area, the top is a very useful structural horizon for estimating depths to the tops of underlying formations (Bristol and Buschbach, 1973).

In this area the Galena is differentiated into four formations (fig. 3): Guttenberg (oldest), Dunleith, Wise Lake, and Dubuque. All are easily recognized in the northwest part of the area. On the basis of outcrop studies, these units are further subdivided into members and beds.

The Guttenberg occurs at the base of the Galena and ranges from 0 to 15 feet thick. Characterized by reddish brown shaly partings and pinkish gray dolomite, the Guttenberg occurs throughout Ogle and Lee Counties but is missing along the Oregon Anticline from Rochelle to Mt. Morris.

The Dunleith Formation consists of a sequence of alternate layers of pure and slightly argillaceous, cherty dolomite approximately 125 feet thick. It overlies the pinkish gray dolomite of the Guttenberg, or, where the Guttenberg is absent, it overlies the finer grained Platteville Group. It underlies the pure, noncherty Wise Lake Formation. The unit is easily recognized in outcrop and subsurface samples in Lee and Ogle Counties, but southeast of this area the formation is not as cherty and argillaceous and becomes very difficult to distinguish from the overlying Wise Lake strata.

The Wise Lake Formation is about 80 feet thick and is the purest dolomite in the Galena Group. In the northwestern part of the area, it can be distinguished readily from the underlying cherty Dunleith Formation and the overlying argillaceous Dubuque Formation.

The Dubuque Formation, which is best developed to the northwest of the study area, is represented by about 40 feet of slightly argillaceous dolomite. It overlies the Wise Lake Formation and is unconformably overlain by the Maquoketa Shale Group. The unit is recognizable in parts of Ogle County, but toward the southeast, it becomes less argillaceous and more difficult to distinguish from the underlying Wise Lake strata. The Dunleith, Wise Lake, and Dubuque are not differentiated in Kendall County and farther southeast.

Maquoketa Shale Group. The Maquoketa Shale Group of the Cincinnatian Series consists chiefly of silty, dolomitic shale with some limestone and dolomite beds commonly present in the middle part of the group. The Maquoketa overlies the relatively pure, medium-grained dolomite of the Galena Group and underlies the argillaceous dolomite and dolomitic shale of the basal Silurian Wilhelmi Formation. Within the area, the group is approximately 100 to 220 feet thick, where covered by Silurian strata. At the bedrock surface, Maquoketa strata occur in juxtaposition with Platteville-Galena and Silurian rocks within the fault zone in parts of Kendall and Will Counties. The Maquoketa is well exposed in outcrops along the Du Page and Des Plaines Rivers in Will County and along Aux Sable Creek in Kendall County. Four formations are differentiated within the area (fig. 3): Scales Shale (oldest), Fort Atkinson Limestone, Brainard Shale, and Neda Formation. These units are easily recognized in outcrop and in subsurface.

The Scales Shale consists of dark gray to dark brown dolomitic shale and silty dolomite that is generally 75 to 100 feet thick. It unconformably overlies the Galena Dolomite and is transitional and conformable with the overlying Fort Atkinson Limestone. Zones of depauperate molluscan fossils and phosphatic pellets are common at the base and locally near the top.

The Fort Atkinson consists of light gray, fine- to coarse-grained, calcarenitic dolomite and limestone with black pyritic specks and abundant fossil debris. In Kendall and Will Counties, the Fort Atkinson is generally about 30 feet thick, but it may vary from 12 to 50 feet thick. Conformably overlying the Scales Shale, it is generally transitional with the overlying Brainard Shale. Locally in western Will County, however, pre-Silurian erosion cut through the Brainard to the relatively resistant carbonate rocks of the Fort Atkinson. Southwest of Joliet along the Du Page River (Sec. 28, T. 35 N., R. 9 E., Will County) the well exposed Silurian Wilhelmi Formation rests on the Fort Atkinson Formation. Subsurface samples and records of borings in the area also show this unconformity.

The Brainard consists of greenish gray, silty, dolomitic shale interbedded with fossiliferous, argillaceous dolomite and limestone. It conformably overlies the Fort Atkinson Limestone, but throughout most of the area the Brainard is unconformably overlain by the Silurian Wilhelmi Formation. The Brainard is generally about 85 feet thick, but in places it is cut out entirely by pre-Silurian erosion.

The Neda Formation, conformably overlying the Brainard in some parts of northeastern Illinois, consists of red shale with flattened spheroids of hematite or goethite. The formation is missing in most of the study area.

Silurian System

The Silurian rocks are confined mainly to the southeastern part of the study area in Kendall and Will Counties (fig. 2). The Silurian System comprises the Wilhelmi, Elwood, and Kankakee Formations of the Alexandrian Series and the Joliet, Sugar Run, and Racine Formations of the Niagaran Series (fig. 3)—all are assigned to the Hunton Limestone Megagroup. Within the area Silurian rocks consist mostly of dolomite. Where the basal Wilhelmi Formation is thick, however, the lower 15 to 20 feet commonly is a gray dolomitic shale. Because of the unconformity at the base, the thickness of the Silurian rocks varies by as much as 125 feet and reaches a maximum of 300 feet in some parts of the area.

The Silurian unconformably overlies the Brainard Formation, but locally the Brainard is cut out, and the Silurian rests on the Fort Atkinson Formation. Except where overlain by Pennsylvanian strata, the Silurian rocks are the youngest Paleozoic rocks in the area. All of the Silurian formations are presently exposed along the fault zone at Channahon Mound.

The Wilhelmi Formation typically consists of a lower dolomitic shale and very argillaceous dolomite that grades to an upper, less argillaceous dolomite. The formation rests unconformably on the Maquoketa Shale Group and conformably underlies the cherty, relatively pure Elwood Formation. Where the Wilhelmi fills local depressions in the underlying Maquoketa, it is up to 100 feet thick but is thin or absent in other areas. The basal shale is sometimes difficult to distinguish from the underlying shale of the Maquoketa Group, but the latter is usually much more fossiliferous and is greenish gray.

The Elwood Formation consists of cherty, relatively pure dolomite, which is generally 25 to 30 feet thick. It is conformable with the underlying shaly Wilhelmi and the overlying greenish to pinkish gray beds of the Kankakee Formation.

The Kankakee Formation consists of about 40 feet of slightly cherty, greenish to pinkish gray dolomite in 2- to

4-inch wavy beds with green shaly partings. It commonly contains rounded sand grains and glauconite at the base. The Kankakee overlies the Elwood and underlies the Joliet Formation. A diastem, represented by a distinctive smooth surface, is prominent at the top of the Kankakee throughout most of the area.

The Joliet Formation consists of about 70 feet of dolomite, which is shaly at the base and becomes purer toward the top. It conformably overlies the Kankakee Formation and underlies the Sugar Run Formation. In outcrop the Joliet is characterized by even beds that are 6 to 12 inches thick.

The Sugar Run Formation consists of about 30 feet of argillaceous, silty, fine-grained, dense, slightly cherty, light gray to buff dolomite. Outcrops in the Channahon Mound area have a smooth, light, weathered face and massive bedding. The Sugar Run overlies and is transitional with the purer dolomite of the Joliet Formation. It underlies the cherty, slightly less argillaceous Racine Formation.

The Racine Formation is generally absent in the area of study; the basal 40 feet, however, are preserved in a graben on Channahon Mound. Here the formation is a very cherty, brownish gray, relatively pure dolomite. The Racine overlies and is transitional with the Sugar Run Formation.

Pennsylvanian System

Pennsylvanian sandstone, shale, and coal, ranging in age from the Morrowan to the Desmoinesian Series, are present in a few small, scattered outliers within the area. In addition, the northern edge of the main body of the Pennsylvanian strata in the Illinois Basin is found along the southeastern edge of the study area in parts of La Salle, Grundy, and Will Counties. The Pennsylvanian rocks rest unconformably on either St. Peter, Platteville, Galena, Maquoketa, or Silurian strata, all of which were regionally tilted and eroded prior to Pennsylvanian deposition. The Pennsylvanian strata appear in crevices, solution-collapse structures, and in lenticular remnants in depressions on the irregular surface of earlier Paleozoic rocks.

Quaternary System

The Paleozoic bedrock formations are overlain by unconsolidated sediments of the Quaternary System that comprise the glacial and alluvial deposits of the Pleistocene Series. The bedrock formations displaced by the Sandwich Fault Zone were truncated to a nearly flat surface; valleys as much as 300 feet deep were cut into the surface when the first glacier—probably the Kansan glacier about 700,000 years ago—covered the area. The Illinoian glaciation, approximately 200,000 years ago, and several Wisconsinan glaciers, from about 75,000 years ago to as recently as 15,000 years ago, covered the area with ice. Thus deep bedrock valleys were buried by glacial drift, loess, and alluvium and are not reflected in the present topography.

The drift consists largely of till, but sand and gravel predominate in the deep part of the bedrock valleys, and lenses are common elsewhere. The Rock, Fox, Du Page, and Des Plaines Rivers have cut shallow channels through the glacial deposits into the bedrock formations, and Holocene (Recent) deposits occur in the river valleys and along smaller streams.

STRUCTURE MAPPING

The top of the Cambrian Franconia Formation was selected as the datum for structural mapping because its distinctive lithology is readily identified in outcrop and in the subsurface; also, it is the shallowest reliable datum present throughout most of the study area. Data were obtained from drilling samples of exploratory borings and water wells, from geophysical and drillers' logs, and from outcrops.

At many localities, the elevation of the top of the Franconia was estimated by determining the approximate interval from a known shallower structural horizon to the Franconia. The interval between the top of the Ancell and the top of the Franconia was particularly useful. In northern Illinois the interval from the Ancell to the Franconia increases in thickness approximately 100 feet per 10 to 15 miles from the northeast to the southwest. Within the area of the Sandwich Fault Zone, the interval ranges from about 500 feet in the Ogle County area to about 700 feet in Will and Grundy Counties. The interval is consistent even where the Ancell thickens at the expense of the underlying Prairie du Chien rocks. The Platteville-Franconia and Galena-Franconia intervals were also useful in estimating the elevation of the top of the Franconia.

Data were plotted on a computer-constructed base map (ILLIMAP, Swann et al., 1970) and contoured in 100-foot intervals. The structure map (fig. 4) depicts the configuration of the top of the Franconia in the fault zone and a strip that is 10 to 20 miles wide on either side of it.

SANDWICH FAULT ZONE

The Sandwich Fault Zone, one of the longest fault zones in Illinois, extends about 85 miles from near Oregon, Ogle County, to near Manhattan, Will County. Although commonly depicted as a single fault on small-scale maps, it is best described as a fault zone, generally ½ to 2 miles wide, consisting of high-angle faults with vertical displacements of a few inches to several hundred feet. It has a maximum cumulative displacement of about 800 feet at its midpoint near Sandwich in southeastern De Kalb County (T. 37 N.,

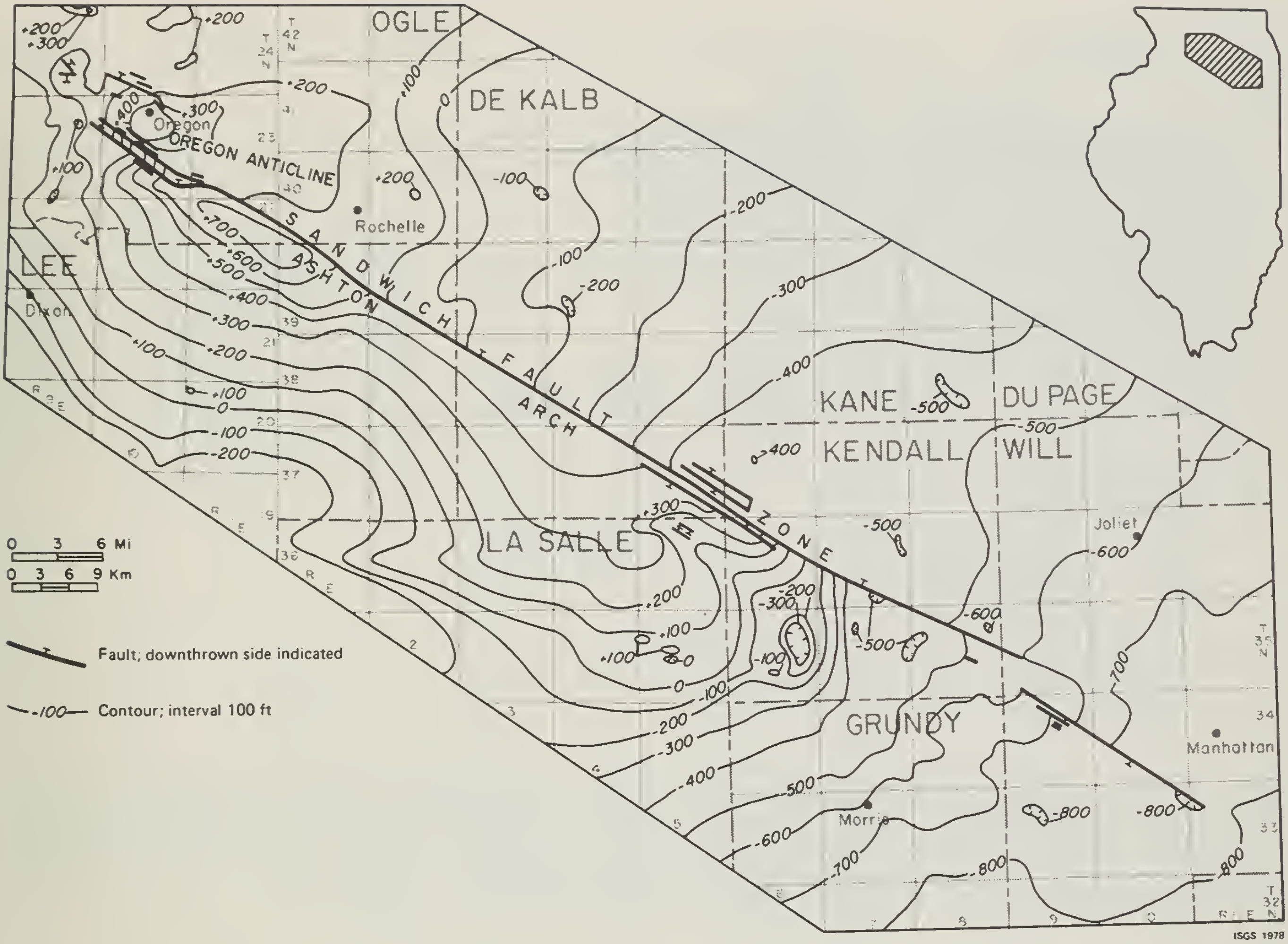

Figure 4. Structure of the top of the Franconia Formation along the Sandwich Fault Zone; datum sea level.

R. 5 E.). Throughout most of its extent, the fault zone is upthrown to the south. The throw diminishes northwest and southeast of the Sandwich area. In Will County, at the eastern end, the fault zone is downthrown to the south with a displacement of about 150 feet.

Where seen in outcrop or interpreted from closely spaced drilling, the fault zone is characterized by high-angle faults that commonly bound grabens and horsts. Reverse faulting, evidenced by repeated stratigraphic section, was observed in the Peoples Gas well 15-J in NE NE NE Sec. 15, T. 35 N., R. 8 E. An apparent normal fault, characterized by a shortened section, was observed in the Kable Printing well in NW SW NW Sec. 27, T. 24 N., R. 9 E.

Because the topography of the area is subdued and the glacial drift covers much of the bedrock, only a few of the individual faults are visible. The fault zone is well defined, however, by the areal distribution of lower Paleozoic strata. On the south side of the fault zone, the upthrown block brings the Cambrian Franconia Formation, the oldest bedrock exposed in Illinois, to the bedrock surface (fig.5).

From the Fox River westward to near Rochelle, the position of the fault zone and the magnitude of displacements are inferred entirely from subsurface information. The outcrops are confined mainly to the areas at both ends of the fault zone.

Sandwich Fault Zone in outcrop

Throughout most of its length, the Sandwich Fault Zone is concealed by surficial deposits of glacial drift, loess, and alluvium. Faults can be observed or inferred, however, from closely spaced outcrops in parts of southern Ogle County, along the Fox River north of Millbrook in Kendall County, and at Channahon Mound northeast of Channahon, Will County (fig. 1).

Ogle County outcrops. Within a large part of southern Ogle County surficial deposits are relatively thin, and bedrock exposures are fairly common. High-angle faults can be observed that trend generally northwest and have displacements ranging from a few inches (fig. 6) to several hundred feet. The structure is complex, and individual faults are very difficult to trace from one outcrop to another. Wide

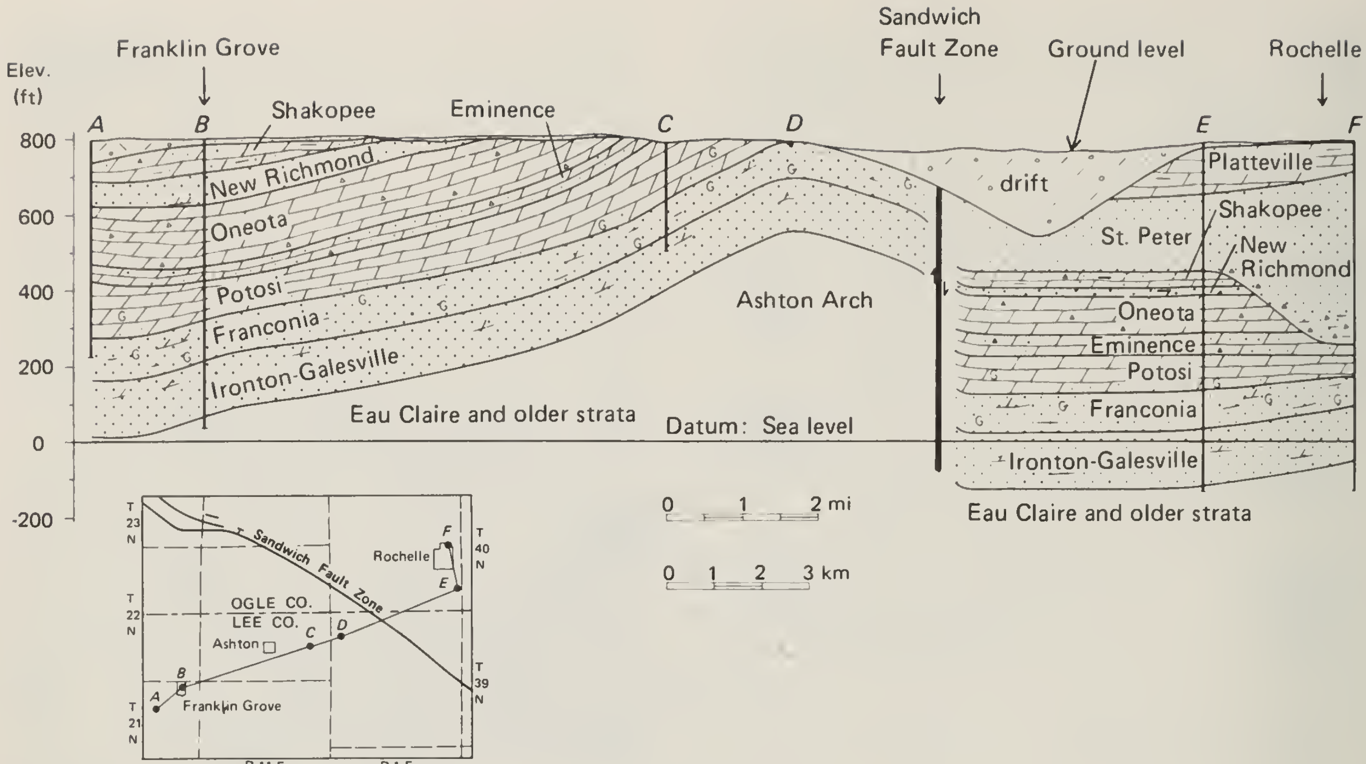

Figure 5. Structural cross section showing stratigraphic relationships across the Sandwich Fault Zone in Ogle and Lee Counties. Interpretation is based on five wells and one outcrop (shown on inset map): A - Natural Gas Pipeline Company well no. 1, SW NW NW Sec. 11, T. 21 N., R. 10 E.; B - Village of Franklin Grove well no. 3, SE NW NW Sec. 1, T. 21 N., R. 10 E.; C - Denton Construction well no. 1, NW NW SW Sec. 25, T. 22 N., R. 11 E.; D - outcrop of Franconia Formation, SE NE NW NE Sec. 7, T. 39 N., R. 1 E.; E - Rochelle City well no. 10, NW NE NE Sec. 36, T. 40 N., R. 1 E.; and F - Rochelle City well no. 7, NE NE NW Sec. 24, T. 40 N., R. 1 E.

Figure 6. Small fault in the New Richmond Sandstone in an outcrop in the Sandwich Fault Zone south of Oregon, Ogle County (SE NE SW Sec. 16, T. 23 N., R. 10 E.).

zones of shearing and intense brecciation occur in places. Localized graben and horst blocks and cross faulting probably account for some of the anomalous stratigraphic relations within the fault zone.

An excellent exposure occurs in a cut along the Burlington Northern Railroad about three miles southwest of Oregon, Ogle County, in the NW NW SE and NE SW Sec. 7, T. 23 N., R. 10 E. (figs. 7a, 7b, 7c, and fig. 8). In this area the fault zone is basically a narrow (1/2 to 3/4 mile wide), northwest-trending graben; Platteville and Galena rocks are displaced downward in juxtaposition with St. Peter Sandstone to the southwest and northeast. Within the graben, strata ranging from the Pecatonica Formation to the Wise Lake Formation are cut by approximately two dozen nearly vertical faults. Most of these faults have a displacement of 1 to 10 feet; however, near the southwest end of the exposure the lower part of the Dunleith is in contact with the Wise Lake, indicating a displacement of about 130 feet. The Pecatonica Formation is exposed at the northeast end of the cut; successively younger rocks are dropped down in fault blocks to the southwest. Flat-lying Wise Lake beds are exposed at the southwest end of the outcrop. Southwest of this point, St. Peter Sandstone is at the bedrock surface (fig. 2), indicating that a major fault or a number of small, closely spaced faults with a

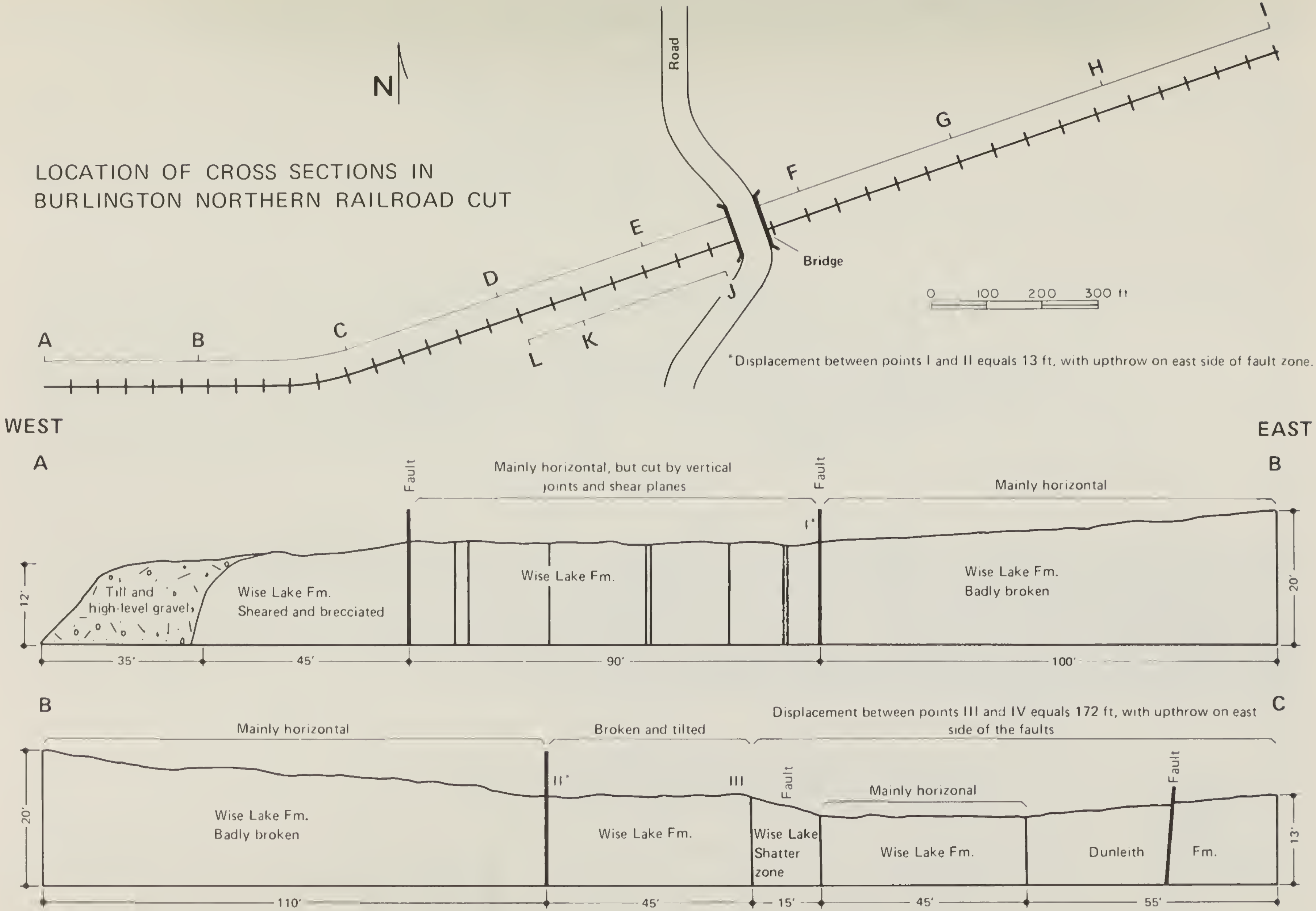

Figure 7a. Cross sections AB and BC of the Sandwich Fault Zone exposed in the Burlington Northern Railroad cut (see fig. 1) about three miles southwest of Oregon, Ogle County (NW NW SE and NE SW Sec. 7, T. 23 N., R. 10 E.). Modified from Templeton and Willman (1952, figs. 15 A-C).

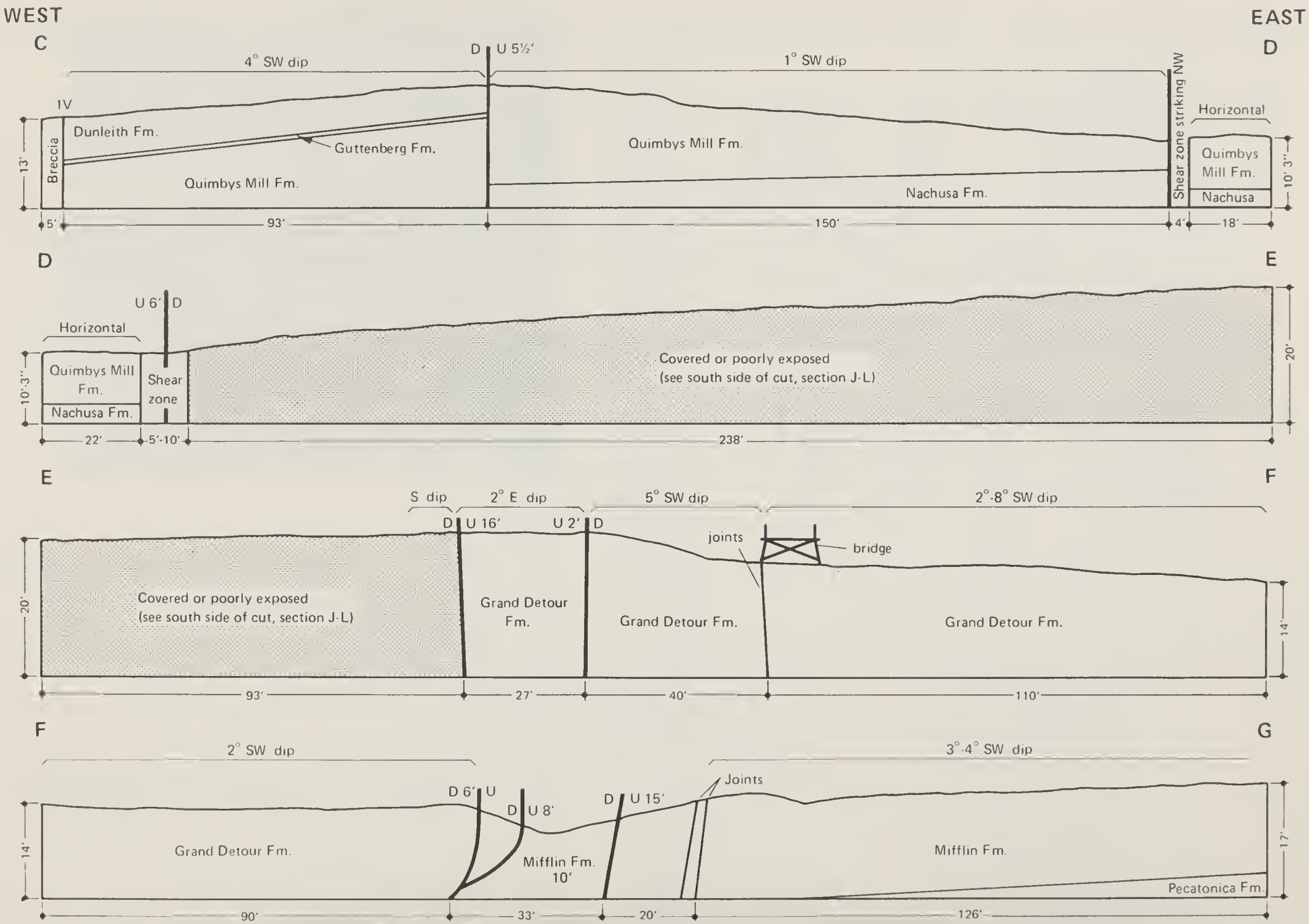

Figure 7b. Cross sections CD, DE, EF, and FG of the Sandwich Fault Zone exposed in the Burlington Northern Railroad cut (see fig. 1) about three miles southwest of Oregon, Ogle County (NW NW SE and NE SW Sec. 7, T. 23 N., R. 10 E.). Modified from Templeton and Willman (1952, figs. 15 A-C). Note: U = upthrown; D = downthrown.

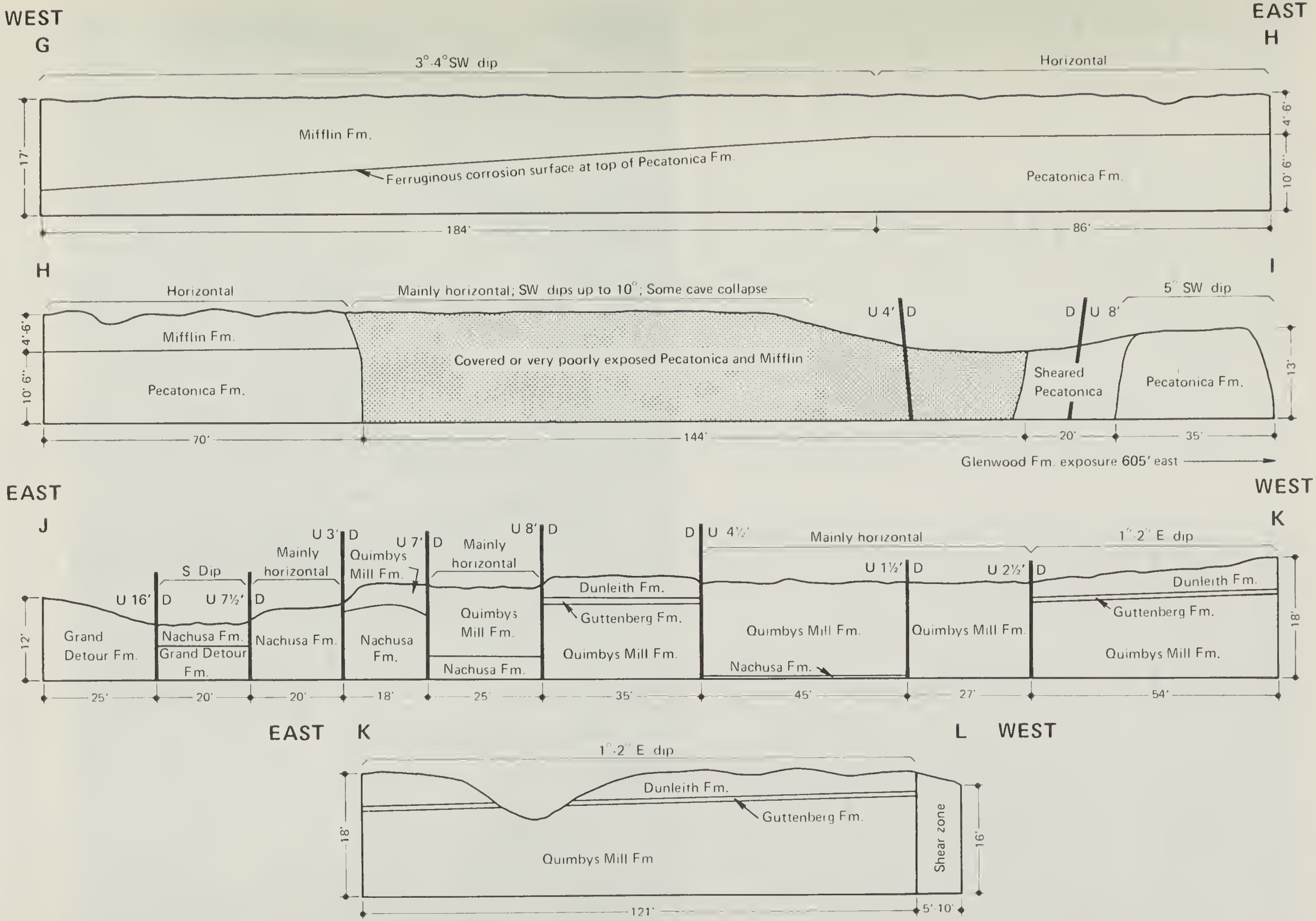

Figure 7c. Cross sections GH, HI, JK, and KL of the Sandwich Fault Zone exposed in the Burlington Northern Railroad cut (see fig. 1) about three miles southwest of Oregon, Ogle County (NW NW SE and NE SW Sec. 7, T. 23 N., R. 10 E.). Modified from Templeton and Willman (1952, figs. 15 A-C).

cumulative displacement of approximately 300 feet have brought dolomite of the Wise Lake Formation into juxtaposition with the St. Peter Sandstone.

All formations in the Pecatonica-Wise Lake interval, known to occur in the area, are exposed along the outcrop. Templeton and Willman (1952, figs. 15 A-C) studied the outcrop in detail when it was relatively well exposed; a modification of their cross sections is shown herein (figs. 7a, 7b, 7c).

The fault zone is not exposed northwest of the Burlington Northern Railroad cut, but it can be observed again about two miles southeast in the bluffs on the west side of the Rock River in SW Sec. 16 and NE SE SE Sec. 17, T. 23 N., R. 10 E., Ogle County. In this area, faulted and brecciated Cambrian and Ordovician rocks crop out intermittently along the northwest side of Highway 2.

The northernmost edge of the main zone of faulting appears to pass through a bluff in SE NE SW Sec. 16. Approximately 20 feet of flat-lying New Richmond Sandstone are exposed on the north and east sides of the bluff, and a zone of chert and sandstone breccia about 200 feet wide is exposed on the south side of the bluff.

Small exposures of breccia and dolomite occur on the north side of a road that branches off Highway 2 in SW NE SW Sec. 16. On the north side of Highway 2 in NE SE SE Sec. 17, several faults displace rocks ranging in age from the Cambrian Potosi Dolomite to Champlainian St. Peter Sandstone. The stratigraphic relations of this outcrop were shown by Willman and Templeton (1951, p. 114, fig. 7).

The clearly defined graben in the railroad cut in Sec. 7 does not appear to continue southeastward to the Highway 2 exposures. In fact, along Highway 2 the rocks are elevated about 200 to 300 feet higher than are those to the northwest or southeast. This anomaly is probably caused by a localized uplift within the fault zone. The structure is difficult to interpret because the St. Peter Sandstone, which bounds the fault zone at the bedrock surface in this area, is very irregular in thickness and lacks identifiable horizons for mapping.

On the east side of the Rock River, the fault zone is partly exposed in several small outcrops.

A quarry near the northern edge of the fault zone in NW NW SW Sec. 23, T. 23 N., R. 10 E., exposes a northwest-trending fault in the Mifflin and Pecatonica Formations of the Platteville Group. The fault has a displacement of about 10 feet. Strata on the upthrown or southwest side of the fault lie flat, whereas the strata on the northeast side are sharply dragged upward.

A small part of the fault zone also is exposed in a quarry in SE NW SE Sec. 25, T. 23 N., R. 10 E. Within the quarry, Platteville rocks are broken by several northwest-trending faults that have as much as 50 feet of dis-

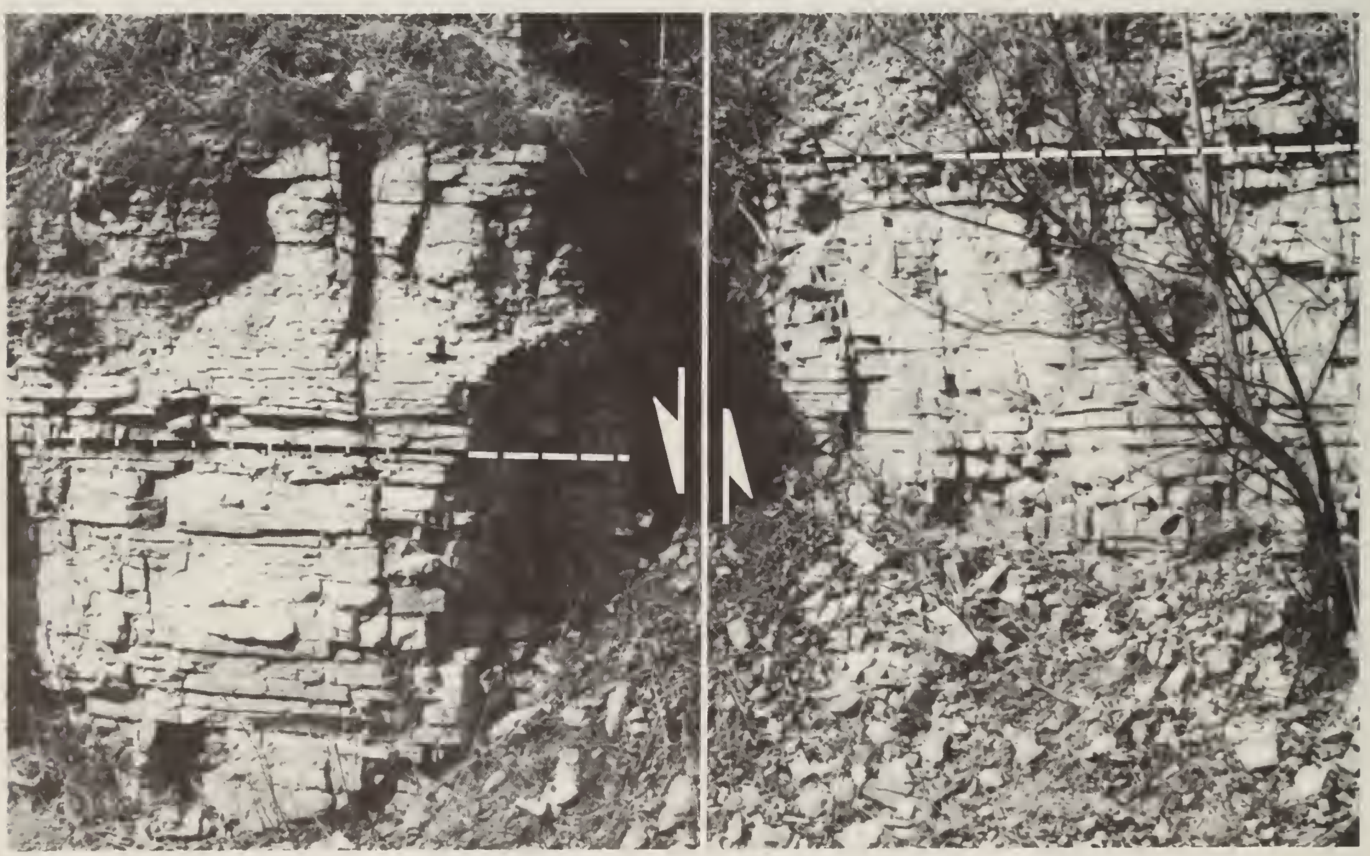

Figure 8. Faulted strata of the Quimbys Mill Formation on the northwest side of the Burlington Northern Railroad (NW SE SW Sec. 7, T. 23 N., R. 10 E.). Beds on the left are downthrown approximately 3 feet.

placement in some places. Shear zones with shattered dolomite exist between some fault blocks. The attitude of beds within the quarry varies. In a nearby hill to the north and northeast, St. Peter Sandstone is exposed at approximately the same elevation as that of the Platteville in the quarry; a possible displacement of over 100 feet between the two exposures is indicated.

Closely spaced outcrops in Sec. 26, T. 23 N., R. 10 E., indicate that a northwest-trending fault (or faults) passes through the southwest part of the section. Flat-lying Oneota Dolomite is intermittently exposed along the banks of a northward-flowing stream from SE SW SW Sec. 26 to a small abandoned quarry in SE NW SW Sec. 26 where 15 feet of Oneota strata are exposed. Jumbled blocks of St. Peter Sandstone crop out on the northwest side of a small hill about 300 feet northeast of the Oneota quarry at approximately the same elevation. Fractured and steeply dipping beds of St. Peter occur along the stream to the north in SW SW NW Sec. 26. The zone of faulting appears to pass between the Oneota quarry (upthrown) and the St. Peter outcrops (downthrown); total displacement is 200 to 300 feet. The fault probably continues south of the prominent bluff of St. Peter Sandstone in the center of the south half of Sec. 26.

Evidence of faulting also can be inferred from outcrops in NE Sec. 31, T. 23 N., R. 11 E. At this locality approximately 15 feet of cherty Oneota Dolomite crop out in a small quarry on the south bank of a stream in NE SW NE Sec. 31. The beds are broken by several high-angle joints but essentially lie flat. Small exposures of the dolomite with characteristic oolitic chert also occur along the stream and tributary ravines for approximately ½ mile to the west. In a prominent hill about 800 feet north of the Oneota quarry, 30 feet of Pecatonica and Mifflin strata (Platteville Group) dip as much as 10° to the south and strike approximately east-west. The lower part of the Pecatonica is concealed, but nearby exposures indicate the formation should be about 25 feet thick at this locality. Thus, the estimated top of the Ancell Group and the top of the Oneota outcrop to the south are at approximately the same elevation. These stratigraphic relations suggest that one or more east-west trending faults with a cumulative throw of about 250 to 300 feet bring the Oneota (upthrown) and Ancell-Platteville (downthrown) rocks into juxtaposition.

Between the southeastern Ogle County area and the Fox River area, the fault zone is covered by relatively thick surficial deposits.

Fox River outcrops. The approximate intersection of the Sandwich Fault Zone and the Fox River can be inferred from outcrops along the river north of Millbrook, Kendall County. Within this area, Galena and younger rocks occur at the bedrock surface on the north side of the fault zone, and Prairie du Chien rocks occur on the south side. About 20 feet of flat-lying Wise Lake strata (Galena Group) crop out on the west side of the river at Millhurst in SW NW SE Sec. 4, T. 36 N., R. 6 E. This is the southernmost outcrop of Galena in the immediate area. One mile southwest of this point, NE NE SE Sec. 8, 10 feet of flat-lying Oneota Dolomite is exposed at about the same elevation; thus a displacement of approximately 600 feet between the two outcrops is indicated.

Along the fault zone between Fox River and Channahon Mound, there are only a few exposures and none show clear evidence of faulting. Maquoketa rocks exposed along Aux Sable Creek in southeast Kendall County (T. 35 N., R. 8 E.) are folded into several broad, low, northwest-trending anticlines, but major faulting is not evident. Neither is faulting evident in the Silurian and Maquoketa exposures along the Du Page River in western Will County (T. 35 N., R. 9 E.).

Channahon Mound outcrops. Channahon Mound is an erosional remnant that was formed at the time of entrenchment of the Des Plaines River Valley in the interval of erosion that followed the Kankakee Flood of Woodfordian age. The mound has about 40 feet of relief and consists of resistant Ordovician and Silurian dolomite covered by as much as 20 feet of the Yorkville Till Member and 10 feet of gravel of the Henry Formation. At the bedrock surface at the north end of the mound, dolomite of the Fort Atkinson Formation is separated from Silurian rocks at the south end by a series of northwest-trending faults. The faults have cumulative displacement that is downthrown to the south; this contrasts with the rest of the fault zone, which is upthrown on the south side.

A large quarry (Vick's Pit, Meyer Material Company) at the southeast end of Channahon Mound, SE Sec. 10, T. 34 N., R. 9 E., exposes a wide area through the fault zone. Faulted and shattered Silurian dolomite is particularly well exposed along a narrow haulage road that was cut nearly perpendicular to the fault zone to connect the north and south parts of the quarry (fig. 9). Every Silurian formation known to occur in northeastern Illinois is exposed in the quarry within several prominent horsts and grabens.

One of the main faults (Fault A, fig. 9; fig. 10) crosses the south entrance to the haulage road on the center line SE SW SE Sec. 10. Fault A displaces the Elwood and Kankakee Formations on the downthrown side adjacent to steeply down-dragged strata of the Wilhelmi Formation on the upthrown (north) side. Stratigraphic relations indicate a displacement of about 30 feet. The Wilhelmi rocks are in a narrow horst block that is bounded by another fauit (Fault B, fig. 9; fig. 11) approximately 300 feet to the north. Fault B has a displacement of about 100 feet and brings the Joliet Formation (downthrown) into juxtaposition with the Wilhelmi (upthrown). For about 400 feet north of Fault B, the Joliet rocks are shattered by numerous high-angle faults and joints (fig. 11).

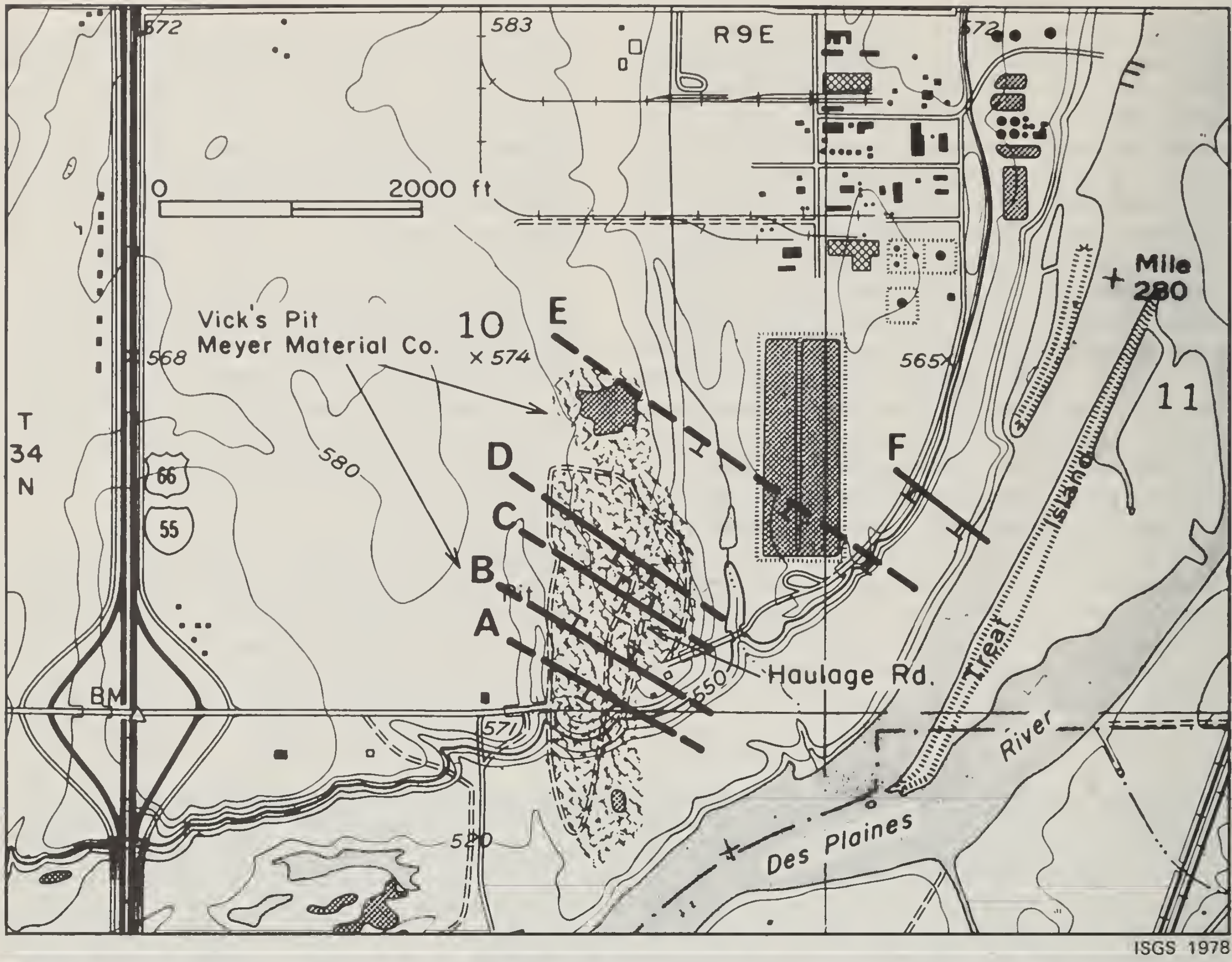

Figure 9. Faults A through F in and near Vick's Pit (Meyer Material Company) on Channahon Mound approximately 2 miles northeast of Channahon, Will County, Illinois.

Near the haulage road entrance to the north part of the quarry (approximately 400 feet north of Fault B) in NW NW SE SE Sec. 10, another major northwest-trending fault (Fault C, fig. 9) is exposed. Fault C brings the Joliet strata, upthrown on the south side, in contact with the basal cherty dolomite of the Racine Formation on the north. Displacement on Fault C is about 40 feet. On the downthrown or north side of Fault C the Racine rocks are intensely shattered in a zone that is approximately 200 feet wide. Stratigraphic relations of individual blocks in this part of the fault zone are very difficult to interpret. Solution cavities are developed in dolomite of the Racine Formation, particularly along joints and faults. Many of the cavities are lined with pyrite and are filled with greenish gray clay and silt, probably of Pennsylvanian age. About 20 feet of late Mississippian and early Pennsylvanian (Russel A. Peppers, personal communications, 1977) sandstone, shale, coal, and conglomerate are preserved in a depression within this shattered zone (fig. 12). Within this depression, several angular blocks of Silurian dolomite are mixed with the Mississippian and Pennsylvanian rocks. The abundant evidence of solution, the draped nature of the strata, and the jumbled occurrence of Silurian and younger rocks suggest that the structure is a collapsed solution cavity. However, the evidence does not preclude the possibility that the Mississippian and Pennsylvanian rocks were let down by tectonic activity in the fault zone.

The zone of shattered Racine rocks is bounded on the north by a fault (Fault D, fig. 9) of about 30 feet that brings the Racine (downthrown on the south) into juxtapositon with the Sugar Run Formation and the basal Racine (upthrown on the north). In some places within the quarry, the beds on the south or downthrown side are steeply dragged down and shattered near the fault. The rocks on the upthrown side dip as much as 10° to the southwest and strike northwest-southeast. At present, dolomite of the Racine is exposed at the bedrock surface in the northernmost part of the quarry.

Figure 10. Faulted Silurian rocks in Vick's Pit (Meyer Material Company) on Channahon Mound (center of south line SE SW SE Sec. 10, T. 34 N., R. 9 E.). Down-dragged beds of the Birds and Schweizer Members of the Wilhelmi Formation (on right) are upthrown in juxtaposition with the Elwood Formation on the left. Displacement on the fault (Fault A, fig. 9) is approximately 30 feet.

Figure 11. Faulted Silurian rocks on west wall of haulage road in Vick's Pit (Meyer Material Company) on Channahon Mound (SE SE SW SE Sec. 10, T. 34 N., R. 9 E.). Fault (Fault B, fig. 9) at left brings the Wilhelmi Formation (upthrown) into juxtaposition with the Joliet Formation (downthrown). The fault has a displacement of about 100 feet. The Joliet rocks are shattered by numerous high-angle normal faults with relatively small displacements. The beveled surface at the top of the bedrock is covered by as much as 20 feet of the Yorkville Till Member.

Flat-lying dolomite of the Fort Atkinson Formation is intermittently exposed along the north and east bluff of Channahon Mound south to a point in the SE SE NW SW Sec. 10. Here, a northwest trending fault (Fault F, fig. 9) brings the Fort Atkinson Formation (upthrown) into juxtaposition with the Wilhelmi Formation (downthrown). A 20-foot wide zone of shattered dolomite and shale marks the position of the fault. A displacement of about 40 feet is indicated by stratigraphic relations.

These field observations indicate that a fault (Fault E, fig. 9), with a downthrow to the south of about 200 feet, probably passes through the covered area between the Wilhelmi outcrops on the east bluff of the mound along the Des Plaines River and the Racine exposure in the quarry to the west. The Racine rocks are preserved in a graben that is bounded by older Silurian rocks on either side.

Geophysical surveys

Refraction seismography and earth resistivity were employed in an attempt to determine the exact position of the Sandwich Fault Zone in an area where only scattered subsurface data, mainly water well samples and drillers' logs, were available for mapping geologic structure. In the search for faults, both techniques are most effective when used where the displaced rocks on either side of the fault differ markedly in lithology (for example, where sandstone is displaced against dolomite). This limitation restricted the use of these techniques to only a few areas along the fault zone.

The refraction and resistivity surveys were employed 6 miles west of Rochelle, Ogle County, adjacent to a north-south road in the center of the north half of Sec. 11 and the center of Sec. 2, T. 22 N., R. 11 E. (fig. 13). Sub-

Figure 12. A solution collapse structure (center at top) in the Silurian Racine Formation in Vick's Pit (Meyer Material Company quarry) at Channahon Mound (NW NW SE SE Sec. 10, T. 34 N., R. 9 E.). Approximately 20 feet of late Mississippian and early Pennsylvanian sandstone, shale, coal, and conglomerate are preserved within the structure. A fault (Fault D) with about 30 feet of displacement brings the Sugar Run Formation (upthrown on left) into juxtaposition with the Racine Formation (downthrown on right).

surface control was provided by water well samples collected at the Fred Bork farm, SE SE NE SW Sec. 2, where St. Peter Sandstone was encountered at an elevation of 690 feet, and at the Cole Tilton farm, NW NW NW NE Sec. 11, where Potosi Dolomite was encountered at an elevation of 680 feet.

Refraction seismography. Refraction seismography was employed to help define the bedrock surface and to aid in the identification of bedrock lithologies within and adjacent to the fault zone. A Geospace 2B 12-channel refraction seismograph equipped with a 600-foot cable with 50-foot geophone spacings was used. A line consisting of eight profiles began at a point 225 feet north of the center of Sec. 11 (fig. 13) and continued north for 4,870 feet, including the 10-foot spacings between shot points of adjacent profiles. Shot holes were augered to 5-foot depths and were loaded with 2 pounds of Nitramon S primer. All eight profiles were reversed by shooting at each end of the geophone spread. Refraction seismic data are shown in table 1.

All the profiles show velocities of 1,250 feet per second in the upper 8 to 12 feet of soil and velocities from 6,000 to 7,000 feet per second in the till unit between the soil and bedrock. Bedrock velocities of profiles 1 through 6 range from 12,000 to 15,000 feet per second; profiles 7 and 8 show a marked decrease in velocity to 9,545 and 9,308 feet per second. Data from nearby water wells indicate that profiles 1 through 6 probably were recorded over the Potosi Dolomite. The velocities recorded in profiles 7 and 8 are typical of sandstone and probably were recorded over St. Peter Sandstone. Displacement of the sandstone against the dolomite occurs near the juncture of profiles 6 and 7 (fig. 13). Faulting may occur throughout the area surveyed, but only the sandstone-dolomite contact provided sufficient contrast in velocities to be recognized.

The depths to bedrock that were determined from the seismic refraction techniques correspond with the depths to bedrock that were encountered in the two control wells. For example, the Tilton well, which is aligned with profile 4, started into bedrock at 100 feet below the surface. The average depth that was recorded for this profile is 107 feet. Likewise, the Bork well, which is aligned with profile 7, encountered bedrock at 95 feet. This profile recorded an average of 92 feet to bedrock.

Earth resistivity profiling. The purpose of this survey was to determine lateral variations in apparent resistivity associated with the changes in bedrock lithology across the fault zone. A Bison Earth Resistivity Meter, Model 2350, was used. Apparent resistivity was measured by moving a Schlumberger electrode configuration as a unit along a line approximately 200 feet west of the seismic refraction line (fig. 13). The Schlumberger configuration (inner electrodes 60 feet apart and outer electrodes 300 feet apart) was oriented in an east-west direction. Eight stations were positioned along a line that corresponded with refraction seismic profiles 5 through 7. Resistivity data are shown in figure 13.

Readings at the three stations that were aligned with seismic profile 7 had high apparent resistivities, about 80 ohm-meters. The five stations that were aligned wih seismic profiles 5 and 6, however, had low apparent resistivities, from 60 to 70 ohm-meters. The stratigraphic section encountered in the two control wells and the anomalous bedrock velocities obtained from the refraction seismic lines indicated that the high apparent resistivities probably were produced by the St. Peter Sandstone and the low apparent resistivities by a dolomite unit, probably the Potosi Dolomite.

Associated structures

The area immediately adjacent to the Sandwich Fault Zone contains a varied and complex assemblage of structural features. The Ashton Arch, Oregon Anticline, and numerous local faults and flexures, including the Sandwich Fault Zone, are superposed on a regional structural setting that is dominated by the Wisconsin Arch, Kankakee Arch, and the La Salle Anticlinal Belt.

The Ashton Arch (Willman and Templeton, 1951, p. 121-122), one of the most prominent structures associated with the fault zone, is a broad, relatively high northwest-trending flexure that occurs in the upthrown (south) side of the fault zone and extends parallel to it from southern Ogle County to northeastern La Salle County. The Ashton Arch is best defined in southern Ogle and northern Lee Counties (fig. 4). The southern flank of the arch merges with the La Salle Anticlinal Belt at approximately the center of Lee County and in the western part of La Salle County. Rocks as old as the Franconia Formation occur at the bedrock surface along the axis of the arch in parts of Ogle and Lee Counties.

In Ogle County, the fault zone seems to terminate in a wide zone of northwest-trending parallel faults. Displacements of these faults generally range from a few inches to several feet and can be observed in numerous outcrops in the Oregon-Mt. Morris area.

The Mud Creek Fault is exposed in a small abandoned quarry in NW SW SE Sec. 30, T. 24 N., R. 10 E., Ogle County. One of the larger well exposed faults in the area, the fault and associated monocline have a cumulative displacement of about 100 feet downthrown on the north (Templeton and Willman, 1952, p. 31-33).

Closely spaced water wells in Mt. Morris indicate that St. Peter Sandstone is at the bedrock surface a short distance from, and at the same elevation as, Galena bedrock (figs. 2 and 4). The St. Peter bedrock seems to be in an uplifted block that is bounded by west- and northwest-trending faults that may have as much as 100 feet of displacement. Although these faults are on trend with the Sandwich Fault Zone, structural control within the area suggests that they are detached from the main part of the fault zone.

A similar uplifted block occurs within a small area on the northeast edge of Oregon, 1,000 feet from E. line, 4,000 feet from N. line, Sec. 3, T. 23 N., R. 10 E. (figs. 2 and 4). At this locality, Potosi and Franconia rocks are in juxtaposition with St. Peter Sandstone. Geologic relations in the area indicate that the Cambrian rocks are in a small fault block that has been uplifted about 300 feet.

The Plum River Fault Zone (fig. 1), which extends in an easterly direction from southern Lynn County, Iowa (Bunker and Ludvigson, 1977), through Carroll County to northern Ogle County, does not appear to be connected with the Sandwich Fault Zone. Both fault zones, however, probably were formed during the same period of deformation.

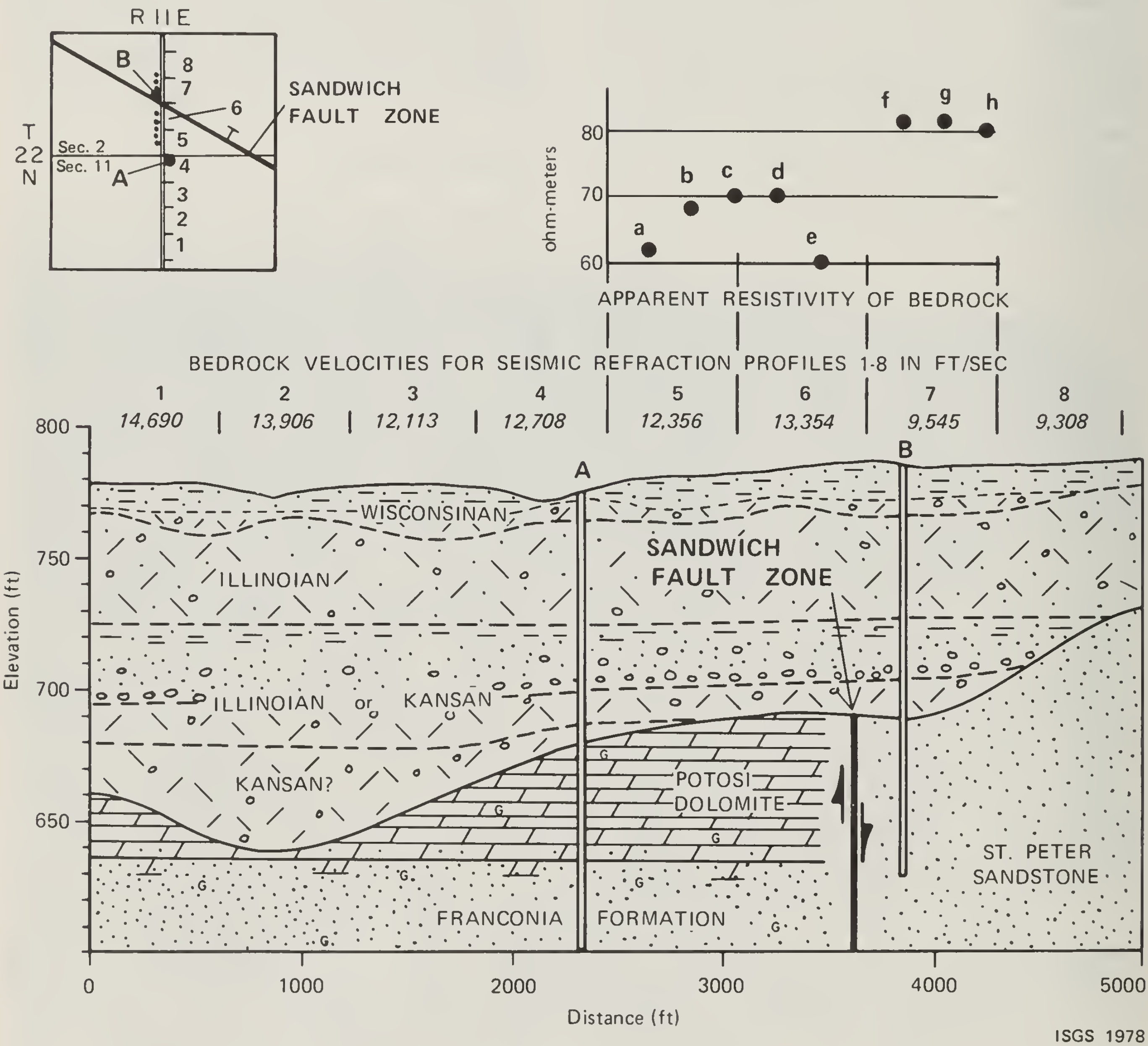

Figure 13. Structural cross section across the Sandwich Fault Zone approximately 6 miles west of Rochelle, Ogle County, Illinois. Interpretation is based on two water wells (A and B), eight continuous refraction seismographic lines (1 through 8), and eight earth resistivity stations (a through h). Bedrock velocities in feet per second are listed within each line along the top of the transect. Velocities of materials that lie above the bedrock are listed in table 1. Glacial drift, loess, and alluvium of Wisconsinan, Illinoian, and possibly Kansan age overlie the bedrock (John P. Kempton, personal communication, 1978). The apparent resistivity of the bedrock in ohm-meters is shown graphically above refraction profiles 5 through 7.

TABLE 1. Data from refraction seismographic survey on the Sandwich Fault Zone. (See figure 13.)

Profile	1	2	3	4	5	6	7	8
Velocity of soil (ft/sec)	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250
Velocity of till (ft/sec)	6,087	6,124	6,012	6,000	6,446	7,138	6,682	6,756
Velocity of bedrock (ft/sec)	14,690	13,906	12,113	12,708	12,356	13,354	9,545	9,308
Thickness of soil (ft)	8.81	7.82	9.90	9.87	9.74	11.04	10.40	12.91
Thickness of till (ft)	109.71	126.50	112.02	97.13	90.29	80.23	81.87	43.71
Depth to bedrock (ft)	118.52	134.32	121.92	107.00	100.03	91.27	92.27	56.62

The Oregon Anticline (Bevan, 1939, p. 1563) is a broad, low flexure that extends along the downthrown side of the Sandwich Fault Zone from Oregon to near Rochelle (figs. 1 and 4). St. Peter Sandstone occurs at the bedrock surface along the axis of the anticline. The Oregon Anticline was thought to be a branch of the Savanna-Sabula Anticline (Templeton and Willman, 1952, p. 8), but the latter structure has been reinterpreted as a fault zone—the Plum River Fault Zone (Kolata and Buschbach, 1976)—that extends north of the Oregon Anticline (fig. 1).

On the north side of the Sandwich Fault Zone from the Rochelle area southeastward through Will County, the structure is dominated by regional dip to the east and southeast; the top of the Franconia Formation is approximately 1,000 feet lower in Will County than in the Rochelle area. Except for a few local anomalies, the dip is fairly uniform throughout the area. Particularly noteworthy is the relatively flat area in northern Kendall County.

Outcrop and subsurface information at the southeast end of the fault zone in Will County is too incomplete to permit recognition of many of the smaller structural features, but probably the fault zone terminates in a wide zone of parallel faults with displacements diminishing to the southeast.

Southeast of the Ashton Arch on the upthrown (south) side of the fault zone, the rocks generally dip to the southeast. The dip is much greater than in the adjacent area north of the fault zone (fig. 4). The structure map reveals a syncline that is parallel to the fault zone and that extends from near Sandwich (north half of T. 36 N., R. 5 E.) to Lisbon (east half of T. 35 N., R. 6 E.).

TECTONIC HISTORY

In northern Illinois there are large gaps in the stratigraphic record; as a result the tectonic history is incompletely known. The bedrock within the area consists almost entirely of Cambrian, Ordovician, and Silurian rocks except for very small, widely separated occurrences of Pennsylvanian rocks in or near the fault zone. With the exception of the slight evidence provided by the Pennsylvanian rocks, the events from Silurian Niagaran time to Pleistocene time can only be inferred from what is known about the regional tectonic history. In northern Illinois the missing record spans major movements shown in the stratigraphic sequence farther south in Illinois at the end of early Devonian time (sub-Kaskaskia unconformity), at the end of Mississippian time (sub-Absaroka unconformity), and possible movements during the interval of more than 150 million years from late Pennsylvanian to late Cretaceous time.

Movement on the Sandwich Fault Zone is clearly post-Niagaran, pre-Illinoian (Pleistocene) in age. Indirect evidence suggests that the major movement probably coincided with the intense crustal activity of late Paleozoic age that resulted in the formation of the La Salle Anticlinal Belt and many other structures in the Eastern Interior Region.

The Precambrian basement of northern Illinois is buried beneath 2,000 to 4,000 feet of Paleozoic rocks. The few deep borings that penetrate the Precambrian indicate that the upper part consists mainly of granite and rhyolite, which range in age from 1.2 to 1.5 billion years before the present. The nearest exposures of Precambrian rocks, in the Baraboo Range of southern Wisconsin, indicate a long, complex history of tectonic activity. Residual effects of the early activity may have influenced subsequent Paleozoic structural development.

Most of the deformation during the Paleozoic appears to have resulted from regional warping and differential sinking (Atherton, 1971, p. 41).

Relative stability over the area during Croixan and Canadian times is indicated by the widespread and generally uniform nature of the rocks (Sauk Sequence). The local absence of a distinctive Croixan (Cambrian) Eminence lithology and the general thinning of the Eminence where recognized in the Ashton Arch area suggest modest structural movement on the arch during latest Cambrian time.

McGinnis suggested (1966, p. 21), on the basis of geophysical data, that a large basement fault zone 20 to 30 miles north of and parallel to the Sandwich Fault Zone was active in Croixan time but ceased its activity before Champlainian time. McGinnis described the fault zone as having an excess of 1,000 feet of displacement down to the south. A graben bounded by the suspected fault zone on the north and the Sandwich Fault Zone on the south was described. The structure is not apparent from current records of borings, but it may later be confirmed by closely spaced deep drilling.

Near the end of Canadian time, regional tilting of the rocks towards the south and uplifting of the Wisconsin and Kankakee Arches occurred. As a result of these movements, several hundred feet of Canadian and Croixan strata were eroded from the area in the long period of subaerial exposure. Subsequently, St. Peter Sandstone overlapped successively older rocks from south to north in northern Illinois. An angular unconformity marks the top of the Sauk Sequence.

In addition to the broad regional movements, local structural activity during post-Shakopee, pre-St. Peter time is evident. Willman and Payne (1943, p. 540, fig. 1) described a small anticline near Millington, Kendall County, Secs. 19 and 30, T. 36 N., R. 6 E., and noted that the Shakopee Dolomite, which is exposed near the crest of the anticline, dips more steeply than in nearby outcrops of St. Peter Sandstone. The structure seems too small to be regarded as the Kankakee Arch, but it may be a local structure that was active in pre-St. Peter time. Cady (1920, p. 111, fig. 10) described a similar feature along a tributary of Franklin Creek in Lee County, NE Sec. 33, T. 22 N., R. 10 E. At this locality, Prairie du Chien beds are sharply folded although nearby outcrops of St. Peter Sandstone are relatively undisturbed. Cady concluded that the structure resulted from pre-St. Peter movement. Buschbach (1964, p. 65) also described an apparent local pre-St. Peter structure near the Des Plaines Disturbance in Cook County. Closely spaced wells in the area directly northwest of the disturbance show differences in the elevation of the Ironton Sandstone, whereas the tops of the Ancell Group in the same wells do not reflect this difference. The evidence suggests that unknown local structural features are concealed beneath the St. Peter Sandstone.

The occurrence of many thin rock units over large areas and little or no change in thickness or lithology indicates that the area was stable again during Champlainian time. There is evidence, however, that the Wisconsin Arch and perhaps other structures in northern Illinois were mildly active at various times. Movement of the Wisconsin Arch, for example, may have caused the minor unconformities between the St. Peter and Glenwood Formations and possibly between the Glenwood and Pecatonica Formations within the area.

Certain stratigraphic anomalies in the Platteville Group suggest local structural activity. At one locality on the flank of the Forreston Dome in western Ogle County, SE NE SE Sec. 32, T. 25 N., R. 7 E., the Pecatonica Formation is missing; the Mifflin Formation rests directly on a thin section of the Glenwood Formation. The stratigraphic relations at this locality and several nearby outcrops suggest that the Forreston Dome may have been active early in Platteville time. The breccia and the contorted beds at the base of the Pecatonica Formation in Matthiessen State Park, La Salle County, NE NE NE Sec. 31, T. 33 N., R. 3 E., also suggest tectonic activity early in Platteville time.

The thinning or absence of the Spechts Ferry and Guttenberg Formations over the Wisconsin Arch perhaps resulted from renewed activity of the Arch early in Galena time. The Guttenberg also thins out over the Oregon Anticline in Ogle County, suggesting local structural activity at that time. During the remainder of Champlainian time and during Cincinnatian through Niagaran time, the area was tectonically stable.

The stratigraphic record in northern Illinois between Niagaran time and Pennsylvanian Desmoinesian time is incomplete. Devonian and Mississippian rocks probably covered the entire area and were eroded in post-Chesterian, pre-Desmoinesian time.

Major folding of the La Salle Anticlinal Belt in northern Illinois in pre-Desmoinesian time is evidenced by the fact that the strata that lie below the Colchester (No. 2) Coal Member (mid-Desmoinesian age) near the crest of the anticline are more intensely folded than superjacent units. Dating of the initial phase of folding is difficult because of the incomplete stratigraphic record. The abrupt thinning of the interval between the Downeys Bluff Limestone and Beech Creek Limestone in the southern part of Crawford County in southeastern Illinois suggests local movement of the La Salle Anticlinal Belt as early as Chesterian time (Elwood Atherton, personal communication, 1977).

Other major tectonic events that are known to have taken place during late Mississippian, early Pennsylvanian time include the principal folding of the Cap au Grès Flexure, initial development of the Mississippi River Arch, tilting of the Illinois Basin down to the south, and uplift of the Nashville Dome (Atherton, 1971, p. 40). This tectonic activity is presumed to have occurred in response to the intense folding and faulting of the Appalachian Orogeny of eastern North America.

The initial deformation of the Sandwich Fault Zone and associated structures probably occurred during the first phase of deformation on the La Salle Anticlinal Belt. In northern La Salle County (T. 35 N., R. 2 and 3 E.), outliers of the Desmoinesian (middle Pennsylvanian) Spoon and Carbondale Formations rest on the St. Peter Sandstone; in the surrounding area, these formations rest on younger rocks. The areal geology indicates that northern La Salle County and possibly the area along the upthrown side of the fault zone were structurally high during pre-Desmoinesian time. This may have been due entirely to uplift on the La Salle Anticlinal Belt, but the structural relationships and the pattern of truncation of the Ordovician and Silurian strata in the area between the anticlinal belt and the fault zone suggest that, more likely, it was due to the combined deformation of these two structures. The discovery of additional outliers of early Pennsylvanian strata overlying Canadian or Croixan rocks farther north in De Kalb, Lee, and Ogle Counties would further support pre-Desmoinesian movement on the Sandwich Fault Zone.

Structural and stratigraphic relations in northern Illinois indicate that a second phase of deformation of the La Salle Anticlinal Belt began after the deposition of the Colchester (No. 2) Coal and possibly continued to the end of or after Pennsylvanian time (Clegg, 1965, p. 93). Further displacement on the Sandwich Fault Zone may have coincided with this renewed activity.

No rocks representing the interval between late Pennsylvanian and Pleistocene time are present in the study area. Coalification studies in La Salle and Grundy Counties indicate that perhaps 3,000 feet or more of Pennsylvanian and younger strata once covered northern Illinois (Damberger, 1971, p. 492) but have since been eroded. A relatively flat erosional surface was cut across the structures; this surface showed only slight relief on the various shale, sandstone, and dolomite formations. Early in Pleistocene (pre-Kansan) time, lowering of the base level and increased runoff resulted in entrenchment of streams, development of mature topography, and topographic adjustment to stratigraphy. Pleistocene deposits as old as the Illinoian glaciation cover the fault zone; however, offsets or disturbed zones that correspond to faults in the bedrock have not been observed. Earthquake epicenters within the area in historic time show no relationship to the Sandwich Fault Zone.

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