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ABSTRACT

Bedrock geologic mapping of the Oregon and Mount Morris 7.5-minute quadrangles was performed to investigate whether any evidence exists to suggest that the Plum River and Sandwich fault zones are connected. Mapping led to the identification of a fault array at the northwest end of the Sandwich Fault Zone that suggests the presence of an accommodation zone between the Sandwich and Plum River fault zones. Uplifted Cambrian and early Ordovician units suggest that the fault array was formed by multiple movements on the main faults. The main faults are likely rooted in basement, and the fault array may be a group of splay faults that propagated northwestern from the tip of the Sandwich Fault Zone. Users of the geologic maps may wonder whether the newly discovered fault array will affect modern seismicity; however, models by Grollimund and Zoback (2001) suggest that seismic risk remains low in Ogle County because northern Illinois lacks a lithospheric weak zone like that underlying the New Madrid Seismic Zone.

INTRODUCTION

For the past 20 years, the Illinois State Geological Survey (ISGS) has created 7.5-minute geologic quadrangle maps (1:24,000 scale) throughout the state as part of the U.S. Geological Survey’s (USGS’s) STATEMAP program. One of the goals of mapping the Oregon and Mount Morris quadrangles (Seid 2010, 2011) was to study the faults in an effort to understand whether the Sandwich and Plum River fault zones are linked. Little is known about the tectonic framework in northern Illinois despite previous mapping efforts (Shaw 1873; Worthen 1875; Weller 1917; Bevan 1924, 1928, 1935a,b; Templeton 1940, 1951; Weller et al. 1961; Willman et al. 1967; McGarry 2000a,b; Kolata 2005, 2012, 2013a,b, 2014). The Sandwich and Plum River fault zones have been interpreted as narrow, high-angle faults formed by crustal extension (Kolata and Buschbach 1976; Kolata et al. 1978).

During this study, the Cambrian exposures near Oregon reported by Bevan (1928, 1935a, 1939) were reexamined, and fault and fold traces were revised in an effort to view the structures as a system of subsidiary faults related to the Sandwich and Plum River fault zones. The purpose of this paper is to describe the faults and explore models to explain their spatial relationship to the Sandwich Fault Zone. This understanding of how fault splays are related to the larger fault zones may be applied to other structures in the Illinois Basin.

GEOLOGIC SETTING

Northern Illinois contains a wide range of Paleozoic strata, with Cambrian units uplifted along the Sandwich Fault Zone (Figure 1). Ordovician and Silurian units are widely present, and small inliers of Devonian strata occur in Rock Island and Henry Counties. Mississippian strata were either eroded or never deposited, but Pennsylvanian units cover the areas southward from the La Salle Anticlinorium into the Illinois Basin and in scattered outliers. The La Salle Anticlinorium, a discrete zone of basement faults with en echelon drape folds in Paleozoic sedimentary cover, extends south-southeastward from the Sandwich Fault Zone (Cady 1920; Clegg 1965). The local bedrock structure is influenced by the Sandwich Fault Zone on the southeast and the Plum River Fault Zone on the north.

The study area consists of the Oregon and Mount Morris 7.5-minute quadrangles, which are located near the southern termination of the Wisconsin Arch and lie at the north edge of the Illinois Basin (Figure 2). Northeast of the study area, the regional dip is to the northeast, away from the Sandwich Fault Zone; southwest of the study area, regional dips are to the southwest. In the study area, Cambrian and Ordovician sedimentary strata are exposed along the Rock River valley and are covered with less than 100 ft (30.5 m) of Quaternary deposits (Piskin and Bergström 1975).

The Sandwich Fault Zone extends from Manhattan in Will County and continues to the northwest for about 85 mi (137 km), to near Oregon. The fault zone is about 0.5 to 2 mi (0.8 to 3 km) wide and is downthrown on the northeast side as much as 800 to 900 ft (244 to 274 m) at its midpoint in southeastern De Kalb County (Templeton and Willman 1952; Kolata et al. 1978). The displacement can be constrained only to post-Silurian, pre-Pleistocene (Kolata et al. 1978), which is to say that the timing is barely constrained at all. The faulting in Oregon and Mount Morris is at the northwestern tip of the Sandwich Fault Zone. Just to the south of Oregon, in the Grand Detour 7.5-minute quadrangle, the structural relief on the Sandwich Fault Zone diminishes from 300 ft (91 m) to zero (Kolata 2012).

The Plum River Fault Zone trends east-west through Carroll and Ogle Counties, extending westward across the Mississippi River into Iowa. The fault zone is defined by a narrow belt of high-angle...
Figure 1 Geologic map of northern Illinois showing the distribution of bedrock units and faults. The study area consists of the Oregon and Mount Morris 7.5-minute quadrangles (rectangles outlined in dashed lines). Modified from Kolata (2005). Dn, downthrown side of fault; Up, upthrown side of fault.
faults with a maximum of 270 ft (82 m) of accumulated displacement, with the north side downthrown (Bunker et al. 1985). The displacement decreases eastward and is 100 to 200 ft (30.5 to 61 m) about 9 mi (14.5 km) north of Oregon. Bunker et al. (1985) cited evidence for Devonian movement, and possible Silurian activity, as well as small post-Pennsylvanian displacement. The fault system was mapped on the basis of limited outcrop control along with borehole data (Kolata and Buschbach 1976). Although not numerous, a few outcrops along the Illinois portion of the fault zone show fracture zones, faults, and cataclastically deformed rock.

The Sandwich and Plum River fault zones underwent multiple movements during the Paleozoic. Both are composed of steeply dipping fractures, commonly near vertical, including normal faults along with local thrust and high-angle reverse types. In addition, Marshak et al. (2003), citing Templeton (1951), mentioned what appear to be horizontal slip indicators on some of the fractures, which suggest an element of strike-slip movement, but it is not as pronounced as on the Cottage Grove Fault System, for example, with its belts of en echelon folds and faults. These structures do not resemble the structural style of the Cap au Grès (Rubey 1952), La Salle (Clegg 1965), and other Ancestral Rocky compressive-block structures with strong fault-propagation folds. In addition, they cannot be explained as products of simple extension like the Wabash Valley Fault System (Bristol and Treworgy 1979). I suggest that both fault zones underwent multiple episodes of movement under different stress fields, creating a combination of compressional and extensional displacements, possibly with a minor amount of strike-slip movement.

The Sandwich Fault Zone contains a narrow fault slice of upthrown Cambrian strata near Oregon, similar to the Horseshoe upheaval that uplifts Devonian strata along the Rough Creek Fault Zone. Nelson (1991, 1995) suggested that the Horseshoe upheaval was caused by compression and uplift followed by subsequent extension in which a narrow slice of Devonian shale remained at the level of Pennsylvanian rocks. The Sandwich Fault Zone may have been uplifted under compression and later dropped down, leaving the Cambrian rocks lying between Ordovician strata.

Multiple episodes of faulting probably occurred in response to tectonic activity along the Laurentian margin. A post-St. Peter, pre-Glenwood movement was documented on the Sandwich Fault Zone in the Grand Detour Quadrangle just south of the study area; this may correlate with the Taconic Orogeny (Seid and Kolata 2011; Kolata 2012). Devonian through Cretaceous units are not present, so it is impossible to know whether movement occurred on the Sandwich Fault Zone during the

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Figure 2  Structure contours on the top of the Cambrian Franconia Formation showing regional structural features. Values are mean sea level; contour interval is 100 ft (30.5 m). Study area is the yellow rectangle outlined in a red dashed line. Modified from Kolata and Graese (1983).
two other documented periods of widespread tectonism in the Illinois Basin—the Devonian event (Nelson and Mar- shak 1996) and the late Mississippian to early Pennsylvanian event (McBride and Nelson 1999). This late Mississippian to early Pennsylvanian movement was a major tectonic event that reactivated many structures in the Illinois Basin, such as the La Salle Anticlinorium (Clegg 1965). No Quaternary movements have been documented in the study area (Kolata and Buschbach 1976; Kolata et al. 1978).

**STRATIGRAPHIC UNITS**

Figure 3 shows the geologic units in the study area. The Cambrian succession is dominated by sandstones and contains minor amounts of limestone and shale. The total thickness of the Cambrian units is approximately 2,200 ft (671 m), and the formations include the Mt. Simon Sandstone, Eau Claire Formation, Galesville Sandstone, Ironton Sandstone, Franconia Formation, and Potosi Dolomite. The Ordovician units are dominated by carbonates, reach an average thickness of about 720 ft (220 m), and consist of the Oneonta Dolomite, New Richmond Sandstone, Shakopee Dolomite, St. Peter Sandstone, Glenwood Formation, Platteville Formation, Decorah Formation, and Galena Formation. The sub-Tippecanoe unconformity (Sloss 1963) is a craton-wide unconformity that occurs at the base of the St. Peter Sandstone.

These sedimentary rocks are prone to brittle deformation (Figure 4), with brittle faults in shales of the Eau Claire Formation, deformation bands—zones of localized cataclasism (Fossen et al. 2007)—in the St. Peter Sandstone and Ironton-Galesville Sandstones, and shear zones of angular breccia and slickensided fault surfaces in dolomites of the Platteville and Galena Formations.

**METHODS**

Outcrops, cores, and drill cuttings were studied to characterize the lithologies and structural features. Accessible outcrops in drainages, road cuts, and quarries were examined in the field. Where field data were not available

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**Figure 3** Stratigraphic column of rock units mapped in the study area. Stratigraphy compiled from Seid (2010, 2011) and Kolata (2013a, 2014). Note that the Platteville and Galena units were lowered from group to formation rank, reflecting a change by Kolata (2013a, 2014) to the older classification by Willman and Kolata (1978).
Figure 4 Examples of brittle deformation features in outcrop and core. (a) Platteville and Galena dolomites sheared into angular breccia in an abandoned quarry along the Mud Creek Fault Zone. (b) Groove lineations and slickensides in Galena dolomite in the wall of an abandoned quarry near Silver Creek. Pencil is oriented parallel to the lineation. (c) Deformation bands in Ironton and Galesville Sandstones from the Dirksen #1 core near Oregon. (d) Deformation bands in the St. Peter Sandstone on the north side of Route 2 between Castle Rock State Park and Oregon. (e) Normal fault with upward splays in shales of the Eau Claire Formation in the Dirksen #1 core hole near Oregon.
(i.e., covered by glacial sediments or urban development), water-well records and cores were utilized to locate stratigraphic contacts in the subsurface. In addition, the ISGS collected three continuous cores during 2010 and 2011 to examine the rock formations in detail (e.g. Dirksen #1, Stuff #1, and MM #1; cores are on file at the ISGS core annex). New detailed light detection and ranging (LiDAR) elevation data were used to provide a high-resolution base map on which to draw geologic contacts.

**STRUCTURAL FEATURES**

The geologic map of the study area showing bedrock formations, faults, folds, and uplifts is illustrated in Figure 5. The faults and folds generally trend northwest, but some small faults trend northeast. Fractures and shear zones, as described by Templeton (1951), are high angle and have displacements of less than 50 ft (15 m). The faults outline a series of horsts and grabens. Templeton (1951) documented several small faults and numerous shear zones that were too small to show at map scale. Descriptions of these structures can be found in his 1942 field notes.

**Mount Morris Uplift**

Correlations among water-well records revealed an uplifted block or dome of St. Peter Sandstone in the town of Mount Morris. The structure is defined by four water wells, which reach St. Peter Sandstone just below surficial sediments. The alignment of these wells suggests that the uplifted block is elongated in the northwest-southeast direction. The amount of displacement is between 100 and 250 ft (30.5 and 76 m), with the highest point in the SW1/4 of the NW1/4 of Sec. 27, T 24 N, R 9 E. This trend follows a small dome that Templeton and Willman (1952) depicted along the axis of the Oregon Anticline. The Mount Morris uplift is in line with uplifted fault blocks of Shakopee Dolomite and a large outcrop area of thick St. Peter Sandstone to the south in the Grand Detour Quadrangle (Kolata 2012).

**Mud Creek Fault Zone**

The Mud Creek Fault (Templeton and Willman 1952), which trends roughly east-west along Mud Creek, is roughly 1,000 ft (305 m) wide and 3 mi (5 km) long (from the center of Sec. 25, T 24 N, R 9 E eastward to the center of Sec. 28, T 24 N, R 10 E). The displacement is downthrown to the north about 30 to 50 ft (9 to 15 m). Faulted, brecciated, and sheared dolomite of the Galena Formation (Dunleith Member) is exposed at many points along the length of Mud Creek (Figure 4a). The fault relationships were well exposed in 1946 in a small quarry located 2,750 ft (838 m) from the west line and 1,100 ft (335 m) from the south line of Sec. 30, T 24 N, R 10 E (Templeton and Willman 1952), but this exposure is now heavily vegetated and on private property. The geologic relationships illustrated by Templeton and Willman (1952) are no longer visible.

**Mud Creek Syncline**

The Mud Creek Syncline (Templeton 1951, p. 55) is a N 80° W to N 85° W-trending fold on the northern (downthrown) side of the Mud Creek Fault. It runs approximately parallel to the fault zone and is characterized by dolomite of the Platteville and Galena Formations dipping about 20° north on the steeper south flank and 5° south on the gentler north flank. The fold is a doubly plunging syncline; the lowest point of the syncline is approximately located at the border between the Oregon and Mount Morris quadrangles. The structure is about 4.5 mi (7.2 km) long and is 0.3 to 1.5 mi (0.5 to 2.4 km) wide, and the structural closure is roughly 50 ft (15 m).

**Stronghold Monocline**

The Stronghold Monocline is a small structure that has brought St. Peter Sandstone to the surface in an area chiefly underlain by the Galena and Platteville Formations. On its north flank, the St. Peter Sandstone strikes N 70° W and dips 20° north-northeast. Templeton (1951, p. 38–45) described a structure in this vicinity that he called the Stronghold Dome, which trends north-south and seems to be a broader feature than the Stronghold Monocline. The major fault trends near the monocline strike about N 59° W.

**Gale Creek Structure (New Name)**

The Gale Creek Structure is defined by two closely spaced outcrops of dipping Shakopee Dolomite surrounded by St. Peter Sandstone in Gale Creek. The Shakopee is uplifted about 130 to 180 ft (40 to 55 m), with the highest point near the center of the W1/2 of Sec. 6, T 23 N, R 10 E. Faulting probably occurred after St. Peter deposition and is related to faults that cut the St. Peter, Platteville, and Galena Formations about 1 mi (1.6 km) southward in the Grand Detour Quadrangle. Field observations could not confirm or deny a fault bounding the uplifted and tilted Shakopee block. Therefore, the structure is interpreted to be a faulted dome, with a concealed fault uplifting the southwest flank. The map view geometry is depicted as an arcuate pod of Shakopee in faulted contact with the St. Peter Sandstone, with a trend of N 50° W. The structure is about 1 mi (1.6 km) in length and occurs in Sec. 6, T 23 N, R 10 E. The Gale Creek Structure occurs at approximately the northwestern end of the Oregon Anticline (Templeton 1951; Templeton and Willman 1952).

**Cambrian Fault Slice Near Oregon**

The Cambrian Franconia Formation is uplifted and dipping 13° northeast on the east side of the Rock River near Oregon. These outcrops were first described by Bevan (1928), but no information could be found in the outcrops during the present study regarding the faults separating the Franconia from the St. Peter Sandstone. Bevan (1935a, 1939) observed an abundant amount of St. Peter silicified fault breccia, an along-strike trend of the breccia, and repeating intervals of the Franconia-Potosi units. With this evidence, he concluded that...
Figure 5 Bedrock geologic map of the Oregon and Mount Morris 7.5-minute quadrangles. Modified from Seid (2010, 2011).
a local thrust fault occurs about 1,500 ft (457 m) from the east line and about 3,300 ft (1,006 m) from the north line of Sec. 3, T 23 N, R 10 E. Templeton (1951, p. 30–37) discussed Bevan’s (1928) conclusion in his report but proposed that St. Peter erosion and possibly faulting could explain the angular relationship between the Franconia and St. Peter at this locality. Without kinematic indicators such as slickensides or en echelon tension gashes, no conclusions can be drawn about whether the faults were high angle, low angle, normal, reverse, or thrust.

DISCUSSION

This study describes how the structures in the Mount Morris and Oregon quadrangles are related to the Sandwich and Plum River fault zones. Findings suggest that the structures in the area between where the faults overlap are part of an accommodation zone. The accommodation zone contains overlapping second-order faults that develop as splay faults from the main structures, which may be deep-seated basement faults that were reactivated throughout the Paleozoic during tectonic events on the continental margin. Multiple episodes of displacement, including normal, reverse, and oblique slip, were possible as different stress fields were applied from the Taconic, Acadian, and Alleghanian Orogenies. Finally, regarding modern seismicity, a study by Grollimund and Zoback (2001) found that earthquakes within the New Madrid and Wabash Valley seismic zones in southern Illinois appear to be related to isostatic rebound of the lithosphere after deglaciation, but their models suggest no elevated seismic strain rate in northern Illinois.

The structures in the study area are probably related to multiple movements on the Sandwich and Plum River fault zones. Gaps in sedimentation and angular unconformities in the Oregon, Mount Morris, and Grand Detour quadrangles indicate tectonic activity during the following times: (1) post-Shakopee, pre-St. Peter, (2) post-St. Peter, pre-Glenwood, and (3) post-Galena, pre-Pleistocene.

Accommodation Zone

Geologic mapping indicates that at the northwest tip of the Sandwich Fault Zone, several northwest-trending faults uplift blocks of older strata. These faults represent an accommodation zone, which is a group of structures that accommodate strain transfer between overlapping normal faults (Figure 6). The terminology around accommodation zones can be complicated and confusing (Faulds and Varga 1998), but earthquakes and fault ruptures are good analogs to help understand the process. Earthquakes occur when the stress on a fault overcomes its frictional resistance, and a rupture nucleates from a point on the fault plane. When the fault ruptures, the slip is not instantaneous; as the seismic waves propagate outward, the slip on the fault propagates from the rupture point toward the fault tips like falling dominoes. Shear stress builds up at the fault tips in a “blowtorch” pattern and triggers subsequent earthquakes on adjacent faults (Stein 1999). An accommodation zone is initiated when shear stress is released by forming new faults beyond the tips of the existing fault. Accommodation zones occur in various tectonic settings around the world, including in the East African Rift (Scott and Rosendahl 1989), in thrust belts in the Canadian Rockies (Dahlstrom 1970), and in the Basin and Range Province of the western United States (Hudson 1997).

In map view, the general strike of the splay faults in the study area is subparallel to the Sandwich Fault Zone (Figure 7). Splay faults may form as a result of several different processes that may operate in conjunction with one another. Second-order fault segments (splay faults) can be produced by the heterogeneous distribution of slip on individual faults (Faulds and Varga 1998). They may also form when the primary fault plane becomes misaligned with principal stresses, at bends in strike-slip faults, or as horsetail splays resulting from propagation at the extensional sides of mode II fault tips (Scholz et al. 2010).

Figure 6 Creation of an accommodation zone. Slip magnitude is typically greatest near the midpoint of the fault and progressively declines toward the tips, where strain is transferred to other normal faults. Modified from Faulds and Varga (1998). Figure courtesy of the Geological Society of America.

Figure 7 Conceptual block diagram of splay faults caused by segmentation at the northwestern end of the Sandwich Fault Zone.

Rooting in Basement Structures

The root of the Sandwich and Plum River fault zones and their associated splay faults may originate in basement structures, similar to other major faults in the midcontinental United States (McBride 1998; McBride and Nelson 1999; Duchek et al. 2004). Seismic reflection profiles across other structures in the Illinois Basin indicate that basement faults are steeply dipping (Potter et al. 1995; McBride and Nelson 1999). Marshak
and Paulsen (1996) attribute high-angle basement faults to Proterozoic extension because rock is four times weaker under extension than compression. Once initiated, basement faults remained as weak zones throughout the Phanerozoic (Marshak and Paulsen 1996). Reactivation of these basement structures and overlying sedimentary strata during the Ordovician (Seid and Kolata 2011), Devonian (Nelson and Marshak 1996), and Pennsylvanian (McBride and Nelson 1999) corresponds to the Taconic, Acadian, Alleghanian, and Ouachita Orogenies along the eastern and southern margins of Laurentia.

**Strike-Slip Component of Displacement**

The majority of the displacement is dip-slip, but a minor strike-slip component is possible. Strike-slip motion occurs on subvertical or steeply dipping faults when horizontal stress is applied in a direction that is oblique to the strike of the fault (e.g., the San Andreas Fault). If an oblique-slip framework is used, the faults and folds in central and southern Ogle County would represent an en echelon array within a 3-mi-wide (5-km-wide) relay or stepover zone between the Sandwich and Plum River fault zones (Figure 8). It is unclear whether the displacement was dextral or sinistral and whether the faulting occurred in one or multiple episodes.

Interpreting the Ogle County faults in a strike-slip framework would be consistent with the view of Marshak et al. (2003, p. 171), who also proposed strike-slip movement on the Sandwich and Plum River fault zones. Marshak et al. (2003) concluded that both extensional and compressional duplexes occur along these structures, which may suggest at least two phases of oblique-slip displacement with different shear senses. An accommodation zone along the Ste. Genevieve Fault Zone in southern Illinois may also have been caused by multiphase oblique-slip displacement (Seid 2013). Similarly, Duchek et al. (2004) suggested a maximum of 984 ft (300 m) of strike-slip displacement on another west-northwest trending structure in the midcontinental United States, the Cottage Grove Fault System.

Oblique-slip faulting has been documented in Laramide-style uplifts in the western United States (Tindall and Davis 1999). Laramide-style uplifts are structurally similar to fault and fold zones in the Midcontinent in that they involve steeply dipping basement faults that are reactivated in response to intracratonic stresses (McBride and Nelson 1999). However, displacements on most structures in the Midcontinent are an order of magnitude lower than the Laramide uplifts.

**Seismic Risk**

Although the craton in the U.S. Midcontinent is not an active plate boundary, it is capable of producing damaging earthquakes and aftershocks, such as the New Madrid events in 1811–1812. Seismic activity in northern Illinois (Figure 9), however, tends to produce earthquakes that are much smaller, less damaging, and less frequent than those in the New Madrid and Wabash Valley seismic zones in southern Illinois. Northern Illinois earthquake epicenters provide information about the existence and location of unknown faults. Information about faults in northern Illinois is sparse because, in most places, bedrock is buried by tens to hundreds of feet of glacial cover (Piskin and Bergström 1975).

Models of the New Madrid Seismic Zone by Grollimund and Zoback (2001) indicate that postglacial isostatic rebound of the lithosphere may trigger intraplate seismicity by causing seismic strain rates to increase from the background level by three orders of magnitude. They predict that in a lithospheric weak zone such as the New Madrid, high rates of seismic energy release will continue for at least the next several thousand years. However, their models show that in northern Illinois, which has no lithospheric weak zone, the predicted present-day seismic strain rate is equal to the background rate, which is between $10^{-12}$ and $10^{-10}\text{yr}^{-1}$ (Anderson 1986; Johnston 1994). This means that seismic risk does not appear to be elevated in the Sandwich and Plum River fault zones or the accommodation zone between them.

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Figure 9 Earthquakes in northern Illinois since 1907. Solid red circles indicate locations of the epicenters. Labels show the year and Richter magnitude. Modified from Carpenter (1999).

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REFERENCES


