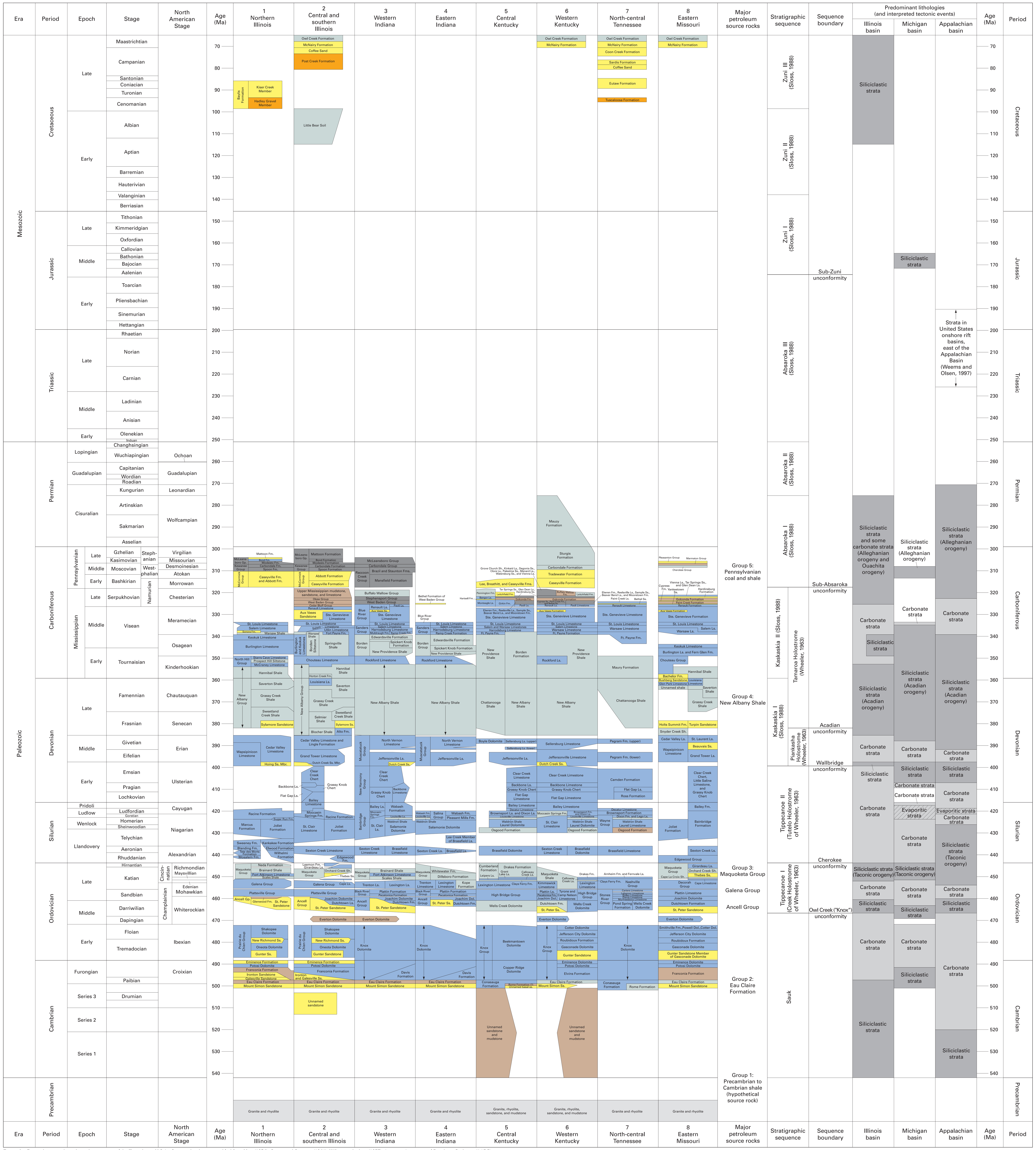

Figure 1.—Regional stratigraphy and petroleum systems of the Illinois basin, U.S.A. Stratigraphic data are modified from Hass (1956), Conant and Swanson (1961), Willman and others (1975), American Association of Petroleum Geologists (AAPG) (1984, 1986), Olive and McDowell (1986), Shaver and others (1986), Thompson (1986), Mancini and others (1996), and Harrison and Litwin (1997). Stratigraphy of the adjacent Michigan basin is from Swezey (2008), and stratigraphy of the adjacent Appalachian basin is from Swezey (2002). The time scale is taken from Gradstein and others (2004). Additional stratigraphic nomenclature is from Harland and others (1990), Babcock and others (2007), and Bergström and others (2008). Stratigraphic sequences and sequence boundary locations are from Sloss (1963, 1988) and Wheeler (1963). Abbreviations used: Dol., Dolomite; Fm., Formation; Gp., Group; Ls., Limestone; Mbr., Member; Sh., Shale; Ss., Sandstone.

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REGIONAL STRATIGRAPHY AND PETROLEUM SYSTEMS OF THE ILLINOIS BASIN, U.S.A.

By
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2009

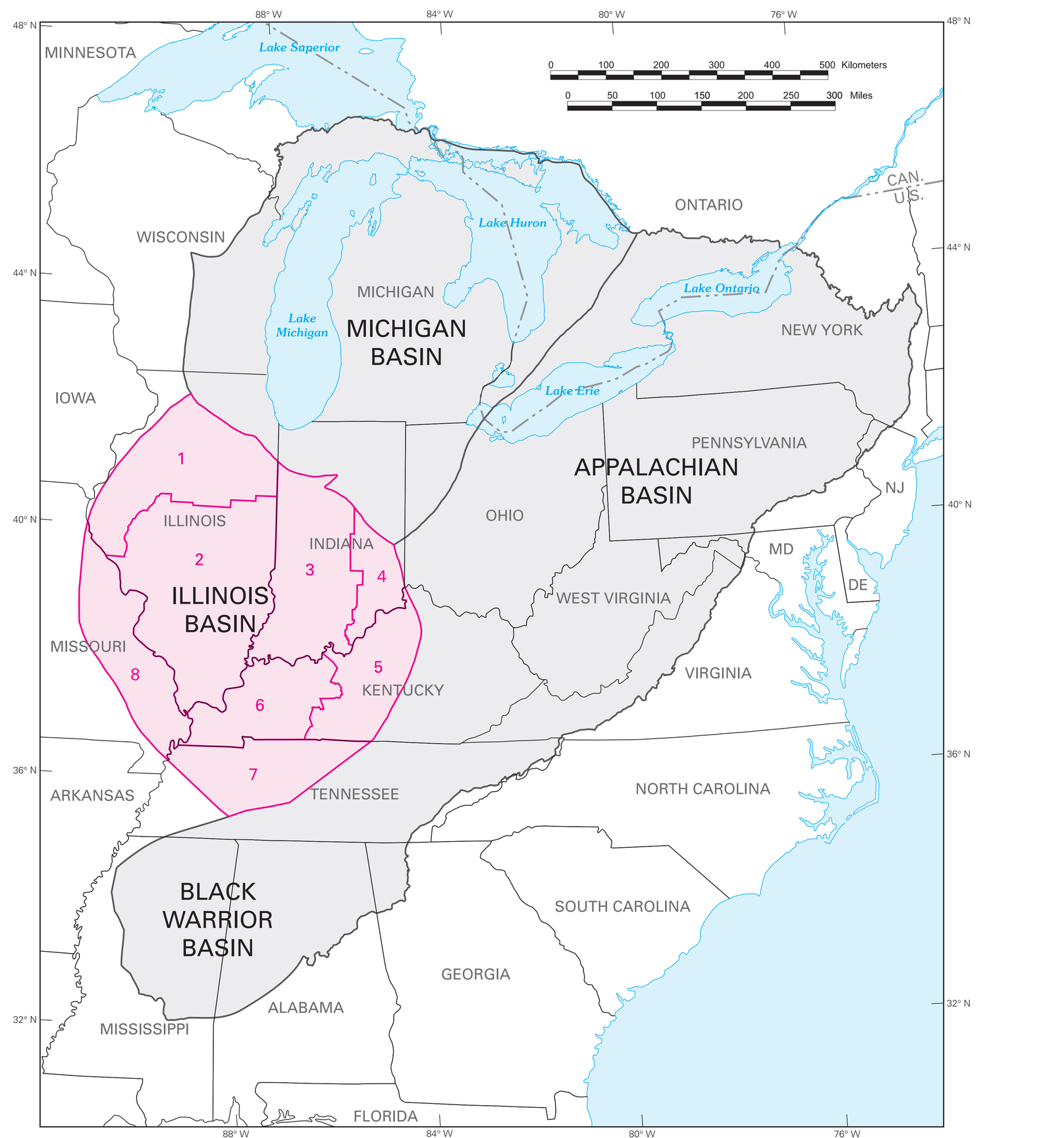

Figure 2.—Extent of the Illinois basin is shown in red. Extents of the Michigan, Appalachian, and Black Warrior basins are shown in gray. The Illinois basin is subdivided into eight regions, and the generalized stratigraphy of these eight regions is shown in figure 1. Column numbers in figure 1 correspond to region numbers in figure 2. Figure 2 is modified from American Association of Petroleum Geologists (1984, 1986) and Swezey (2008).

EXPLANATION OF LITHOLOGY

- Carbonate rock or chert
- Conglomerate
- Sandstone
- Interbedded sandstone and mudstone
- Interbedded sandstone, mudstone, carbonate rock, and coal
- Siliciclastic mudstone
- Section not present

Table 1.—Petroleum source rocks and associated major petroleum plays of the Illinois basin (modified from Swezey and others, 2007b).

Petroleum source rocks of the Illinois basin	Major petroleum plays of the Illinois basin
Group 5: Pennsylvanian coal and shale	Pennsylvanian coal beds
Group 4: Devonian to Mississippian New Albany Shale	Pennsylvanian sandstone Upper Mississippian sandstone Lower Mississippian carbonate Lower Mississippian Borden Formation (Group) Devonian to Mississippian New Albany Shale (Group) Middle Devonian carbonate Middle Devonian Dutch Creek Sandstone Lower Devonian carbonate Upper Silurian carbonate (reefs) Lower Silurian calcareous siltstone (hypothetical) Lower Silurian carbonate Cambrian to Ordovician carbonate, along southeastern margin of basin
Group 3: Ordovician Maquoketa Group, Galena Group, and Ancell Group (Dutchtown Limestone and Joachim Dolomite)	Ordovician Maquoketa Group (hypothetical) Ordovician Dutchtown Limestone to Galena Group Ordovician St. Peter Sandstone and Everton Dolomite (hypothetical)
Group 2: Cambrian Eau Claire Formation	Cambrian to Ordovician Knox Group (hypothetical) Cambrian Mount Simon Sandstone and Eau Claire Formation (hypothetical)
Group 1: Precambrian to Cambrian shale (hypothetical) older than the Cambrian Eau Claire Formation	Precambrian to Cambrian rift-fill strata (hypothetical) older than the Cambrian Eau Claire Formation

INTRODUCTION

This publication combines data on Paleozoic and Mesozoic stratigraphy and petroleum geology of the Illinois basin, U.S.A., in order to facilitate visualizing the stratigraphy on a regional scale and visualizing stratigraphic relations within the basin. Figure 1 presents these data in eight schematic chronostratigraphic sections arranged approximately from north to south, with time denoted in equal increments along the sections, and figure 2 shows the areal extent of this structural basin. The stratigraphic data are modified from Hass (1956), Conant and Swanson (1961), Willman and others (1975), American Association of Petroleum Geologists (AAPG) (1984, 1986), Olive and McDowell (1986), Shaver and others (1986), Thompson (1986), Mancini and others (1996), and Harrison and Litwin (1997). The time scale is taken from Gradstein and others (2004). Additional stratigraphic nomenclature is from Harland and others (1990), Babcock and others (2007), and Bergström and others (2008). Stratigraphic sequences as defined by Sloss (1963, 1988) and Wheeler (1963) also are included, as well as the locations of major petroleum source rocks and major petroleum plays. The stratigraphic units shown in figure 1 are colored according to predominant lithology, in order to emphasize general lithologic patterns and to provide a broad overview of the Illinois basin. For the purpose of comparison, three columns on the right side of figure 1 show schematic depictions of stratigraphy and interpreted events in the Illinois basin and in the adjacent Michigan and Appalachian basins (locations shown in figure 2). Data for the Michigan basin column are modified from Swezey (2008), whereas data for the Appalachian basin column are modified from Swezey (2002).

GENERAL STRATIGRAPHY

Figure 1 shows the predominant lithologies for given areas within the Illinois basin. The oldest of these rocks is 1,500- to 1,420-Ma (Mesoproterozoic) granite and rhyolite (Kolata and Nelson, 1990; Van Schmus and others, 1996), which are designated as Precambrian on figure 1. The Precambrian granite and rhyolite are capped by an unconformity, which is overlain by Cambrian siliciclastic strata. The Cambrian siliciclastic strata, in turn, are overlain by uppermost Cambrian and Ordovician carbonate strata with some beds of siliciclastic strata (~497–452 Ma). There is a distinct interval of siliciclastic strata (St. Peter Sandstone) that represents a relatively short duration (~467–460 Ma) within the overall package of Ordovician carbonate rocks. The St. Peter Sandstone is overlain by Middle and Upper Ordovician carbonate strata (~460–452 Ma), with minor beds of evaporites within the Everton Dolomite and Joachim Dolomite. These carbonate strata are overlain by Upper Ordovician siliciclastic strata (~452–444 Ma), which exhibit a general basinwide pattern of finer grained rocks overlain by coarser grained rocks. The Upper Ordovician siliciclastic strata are overlain by Lower Silurian through Middle Devonian strata (~444–385 Ma) of predominantly carbonate composition. There is a distinct interval of siliciclastic rocks (Dutch Creek Sandstone and stratigraphically equivalent Hoing Sandstone Member of the Cedar Valley Limestone) that represents a relatively short duration (~399–398 Ma) within the Lower Silurian through Middle Devonian carbonate package. The Lower Silurian through Middle Devonian carbonate strata are overlain by Upper Devonian through Lower Mississippian siliciclastic strata (~385–353 Ma), which are, in turn, overlain by Middle Mississippian carbonate strata (~353–326 Ma). Within these Middle Mississippian carbonate strata, a distinct interval of siliciclastic strata is mapped as the Borden Siltstone, Borden Formation, or Borden Group, and minor beds of evaporites are present within the St. Louis Limestone. In turn, the Middle Mississippian carbonate strata are overlain by Upper Mississippian mudstone, sandstone, and limestone (~326–318 Ma). The Upper Mississippian strata are overlain by Pennsylvanian through Permian strata (~318–276 Ma) that are predominantly siliciclastic but also contain some beds of coal and limestone. The Pennsylvanian through Permian strata are overlain by Cretaceous siliciclastic strata (~115–66 Ma).

As for correlations with the sequences of Sloss (1963, 1988) and Wheeler (1963), the Illinois basin contains the following five major sequences: Sauk, Tippecanoe, Kaskaskia, Absaroka, and Zuni. These five sequences are bounded by unconformities that have been identified across most of North America. The identification of these sequences provides a framework for stratigraphic correlations with other geologic basins and also provides a framework for discussing the respective influences of tectonic activity, climate, and sea level on the generation and preservation of strata. Additional unconformities of more local extent are present within the Illinois basin, but figure 1 shows only the major unconformities identified by Sloss (1963, 1988) and Wheeler (1963).

In the Illinois basin, the Sauk Sequence is bounded at the base by the unconformity between the Precambrian basement and the overlying Cambrian siliciclastic strata and at the top by the Owl Creek unconformity, which lies at the base of the St. Peter Sandstone and equivalent units. Sloss (1963, 1988) divided the Sauk Sequence into three units (Sauk I, Sauk II, and Sauk III), but only the Sauk II and Sauk III units are present in the Illinois basin. The Mount Simon Sandstone is part of the Sauk II unit, whereas the Franconia Formation is part of the Sauk III unit. However, the Sauk II-Sauk III boundary is not well documented in this region and therefore is not shown in figure 1.

The Tippecanoe Sequence is bounded at the base by the Owl Creek unconformity and at the top by the Wallbridge unconformity, which lies at the base of the Dutch Creek Sandstone and equivalent units. The Tippecanoe Sequence was divided by Sloss (1988) into a lower unit (Tippecanoe I) and an upper unit (Tippecanoe II). Wheeler (1963) referred to the strata of this lower unit as the Creek Holostrome, and he referred to the upper interval as the Tutelo Holostrome. In the Illinois basin, the boundary between these two Tippecanoe units is an unconformity between the Upper Ordovician Maquoketa Group (and stratigraphically equivalent Cincinnatian rocks) and the overlying Lower Silurian carbonate strata (for example, the Edgewood Formation, the Brassfield Limestone, and the Sexton Creek Limestone). Although Wheeler (1963) named this unconformity the "Taconic discontinuity," Dennison and Head (1975) later proposed that the name be replaced by "Cherokee unconformity," which is a Native American name (as are the names proposed by Sloss and Wheeler for the stratigraphic sequences) and does not imply an association with the Taconic orogeny.

The Kaskaskia Sequence, which lies above the Tippecanoe Sequence, is bounded at the base by the Wallbridge unconformity and at the top by the sub-Absaroka unconformity, which is associated with the Mississippian-Pennsylvanian boundary. More recent work, however, suggests that the sub-Absaroka unconformity is actually of early Pennsylvanian age (Ettensohn, 1994). The Kaskaskia Sequence was divided by Sloss (1988) into a lower unit (Kaskaskia I) and an upper unit (Kaskaskia II), with the boundary between the two units being "near the close of Devonian time" (Sloss, 1988, p. 35). In figure 1, this Kaskaskia I-Kaskaskia II boundary is shown at the Devonian-Mississippian boundary. Wheeler (1963) also divided the strata between the Wallbridge unconformity and the sub-Absaroka unconformity into two units, referring to the lower unit as the Piankasha Holostrome and the upper unit as the Tamaroa Holostrome. However, the boundary between these two units designated by Wheeler is not the same as the Kaskaskia I-Kaskaskia II boundary of Sloss. Wheeler (1963) indicated that the boundary between the Piankasha Holostrome and the Tamaroa Holostrome is the Acadian unconformity, which is located at the base of the Upper Devonian Sylamore Sandstone (and stratigraphically equivalent units).

The Absaroka Sequence, which lies above the Kaskaskia Sequence, is bounded at the base by the sub-Absaroka unconformity and at the top by the sub-Zuni unconformity. The Absaroka Sequence was divided by Sloss (1988) into a lower unit (Absaroka I), a middle unit (Absaroka II), and an upper unit (Absaroka III). In the Illinois basin, however, only Absaroka I strata have been preserved.

The Zuni Sequence, which lies above the Absaroka Sequence, is bounded at the base by the sub-Zuni unconformity and at the top by the sub-Tejas unconformity, which is of Paleocene age (not shown in figure 1). The Zuni Sequence was divided by Sloss (1988) into a lower unit (Zuni I), a middle unit (Zuni II), and an upper unit (Zuni III). In the Illinois basin, however, only Zuni II and Zuni III strata have been preserved.

Petroleum Source Rocks

The names of the major petroleum source rocks (rocks from which petroleum is derived) in the Illinois basin are taken from Swezey and others (2007a,b). These source rocks, which are presented in figure 1 and in table 1, fall into five distinct groups according to stratigraphic age. Group 1 consists of hypothetical source rocks of Precambrian and Cambrian shale older than the Cambrian Eau Claire Formation. Group 2 consists of shale within the Cambrian Eau Claire Formation. Group 3 consists of Ordovician source rocks, including shale in the Ordovician Ancell Group (Dutchtown Limestone and Joachim Dolomite), shale within the Ordovician Galena Group (and equivalent strata), and shale within the Ordovician Maquoketa Group. Group 4 consists of shale within the Upper Devonian to lower Mississipppian New Albany Shale (and equivalent strata). Group 5 consists of Pennsylvanian coal and shale. Although some beds of organic-rich shale are present within Mississippian carbonate strata (Ridgley and Nuccio, 1995), these shale beds are not considered to be major source rocks because they are thin and have very limited lateral extent. Likewise, some beds of lignite have been identified in the Cretaceous McNairy Formation in Calloway County, Ky. (Olive, 1965; Hower and others, 1990), and it is conceivable that this lignite might be a source of biogenic gas. However, these lignite beds are not considered to be a major source rock because they, too, are thin and have very limited lateral extent.

Most of the petroleum source rocks in the Illinois basin are thought to have generated thermogenic oil and gas. Much of the gas in the Devonian-Mississippian New Albany Shale, however, is of biogenic origin (McIntosh and others, 2002). Likewise, much of the gas in the Pennsylvanian coal is of biogenic origin (Tedesco, 2003; Drobniak and others, 2004; Morse and others, 2005).

Petroleum Plays

A petroleum play is defined as a group of drilling prospects having similar geologic characteristics that control production (Magoon and Dow, 1994; Patchen, 1996). Plays are commonly designated in terms of stratigraphy, although play names can also be modified by reference to type of petroleum trap. In U.S. Geological Survey oil and gas assessments, petroleum plays are referred to as "assessment units." The major petroleum plays or assessment units in the Illinois basin include sandstone, carbonate, and shale (table 1). The assessment units are distributed more widely throughout the stratigraphic sections than the source rocks, but most of the assessment units do show some stratigraphic proximity to the source rocks. As outlined in Swezey and others (2007a,b), the Precambrian to Cambrian source rocks have supplied petroleum to Precambrian through Ordovician strata. The Ordovician source rocks have supplied petroleum only to Ordovician strata. The Devonian to Mississippian New Albany Shale (Group) has supplied petroleum to Cambrian to Ordovician strata along the southeastern margin of the basin and to Silurian through Pennsylvanian strata throughout most of the rest of the basin. The Pennsylvanian coal and shale source rocks have supplied petroleum only to Pennsylvanian strata.

DISCUSSION

The Paleozoic lithostratigraphy of the Illinois basin is strikingly similar to that of the Michigan basin and the Appalachian basin, and thus it appears that the three basins have had a similar history and have responded in a similar manner to changes in tectonics, sea level, and climate. Much of the Paleozoic record within the Illinois basin, the Michigan basin, and the Appalachian basin is composed of carbonate strata. Accordingly, the three basins were essentially carbonate basins during the Paleozoic, with the appearance of non-carbonate strata denoting unusual events. A few notable exceptions to the similarities of Paleozoic stratigraphy are (1) the Cambrian strata, which are primarily sandstone in the Illinois and Michigan basins and are primarily carbonate in the Appalachian basin and (2) the Upper Silurian strata, which are primarily carbonate in the Illinois basin and the southern Appalachian basin and are primarily evaporitic strata in the Michigan basin and the northern Appalachian basin.

Most of the siliciclastic strata in the Illinois basin are traditionally interpreted as being associated with tectonic events (for example, see Quinlan and Beaumont, 1984; Kolata and Nelson, 1990). The Upper Ordovician to Lower Silurian siliciclastic strata are associated with the Taconic orogeny in the Appalachian basin, the Middle Devonian to Middle Mississippian siliciclastic strata are associated with the Acadian orogeny in the Appalachian basin, and the Upper Mississippian to Permian siliciclastic strata are associated with the Alleghanian orogeny in the Appalachian basin. Upper Pennsylvanian (upper Missourian) to Permian siliciclastic strata are also associated with the Ouachita orogeny, which occurred south of the Illinois basin (Nelson and others, 1990). Cretaceous siliciclastic strata are coincident with both the Laramide orogeny, which occurred west of the Illinois basin (for example, Maxon and Tikoff, 1996; English and Johnston, 2004), and with a time of relatively high eustatic sea level (Miller and others, 2005). Cecil and others (2003, 2004), however, have suggested that climate also exerts an important control on lithostratigraphy. Additional support for the role of climate is suggested by the observation that the three Appalachian orogenies (Taconic, Acadian, and Alleghanian) are approximately coincident with the three major glaciations that occurred during the Paleozoic (as described by Crowell, 1999). In the Illinois basin, a major unconformity (sequence boundary) is present with each package of Paleozoic siliciclastic strata associated with an orogeny. The Cherokee unconformity is located at the top of the siliciclastic package associated with the Taconic orogeny. The Acadian unconformity is located at the base of sandstone (Sylamore Sandstone, Holts Summit Formation, and Turpin Sandstone) overlain by finer grained rocks in the lower part of the siliciclastic package associated with the Acadian orogeny. The sub-Absaroka unconformity is located at the base of sandstone (Caseyville Formation) overlain by finer grained rocks in the lower part of the siliciclastic package associated with the Alleghanian orogeny.

By comparing the Paleozoic stratigraphic records of the Illinois and Appalachian basins, it appears that most of the Upper Ordovician and Upper Devonian siliciclastic strata began to accumulate in the Appalachian basin before they began to accumulate in the Illinois basin. In both instances, subsidence in the Appalachian basin may have initially trapped siliciclastic sediments in that basin, allowing carbonate sediments to continue accumulating in the Illinois basin. Eventually, however, siliciclastic sediments extended beyond the Appalachian basin and into the Illinois basin, shutting down carbonate production and leading to an overall change from carbonate accumulation to siliciclastic accumulation in the Illinois basin. A similar sequence of events also occurred during the Mississippian. During the Early Mississippian (late Kinderhookian), carbonate strata (Chouteau Limestone and Rockford Limestone) were re-established in the Illinois basin, while siliciclastic strata continued to accumulate in the Appalachian basin. However, during the Early to Middle Mississippian (Osagean), siliciclastic strata in the Appalachian basin extended into the Illinois basin, shutting down carbonate production and leading to an overall change from carbonate accumulation to siliciclastic accumulation as the Borden Siltstone (and equivalent strata).

In addition to the major packages of siliciclastic strata, there are two minor packages of Paleozoic siliciclastic strata that accumulated in the Illinois basin: the St. Peter Sandstone at approximately 467 to 460 Ma, and the Dutch Creek Sandstone (and stratigraphically equivalent Hoing Sandstone Member of the Cedar Valley Limestone) at approximately 399 to 398 Ma. These sandstones are present within predominantly carbonate strata and are not associated with significant fining-upward or coarsening-upward trends. Furthermore, they represent relatively short durations and are not associated with major orogenies. These sandstones may owe their origin primarily to changes in climate and (or) sea level. A possible scenario is that the two sandstones are of eolian origin, or that they originally were eolian sediments that were subsequently redeposited in a subaqueous environment (Berkey, 1906; Grabau, 1940; Summerson and Swann, 1970; Tissue and Langenheim, 1979; Dott and others, 1986).

In the Illinois basin, some of the major petroleum source rocks (Precambrian to Cambrian shale, Cambrian Eau Claire Formation, Ordovician Maquoketa Group, Devonian to Mississippian New Albany Shale, and Pennsylvanian coal and shale) are associated with siliciclastic strata, whereas other petroleum source rocks (Cambrian Eau Claire Formation, Ordovician Dutchtown Limestone, Ordovician Joachim Dolomite, and Ordovician Galena Group) are associated with carbonate strata. Nevertheless, the recognition of five discrete groups of petroleum source rocks provides a context for evaluating hydrocarbon resources of the Illinois basin in terms of five petroleum systems (in the sense of Magoon and Dow, 1994).

In summary, the Illinois basin of the United States contains Paleozoic and Mesozoic strata ranging from Cambrian to Cretaceous in age (fig. 1). These strata represent parts of the Sauk, Tippecanoe, Kaskaskia, Absaroka, and Zuni Sequences of Sloss (1963, 1988) and Wheeler (1963). Illinois basin strata are characterized by distinct lithologies that persisted geologically on the order of tens of millions of years. Most of the Cambrian strata (~542–497 Ma) are predominantly siliciclastic. The uppermost Cambrian to Upper Ordovician strata (~497–452 Ma) are predominantly carbonate. The uppermost Ordovician strata (~452–444 Ma) are predominantly siliciclastic, associated with the Taconic orogeny. The Lower Silurian to Middle Devonian strata (~444–385 Ma) are predominantly carbonate. The Upper Devonian through Lower Mississippian strata (~385–353 Ma) are predominantly siliciclastic, associated with the Acadian orogeny. The Middle Mississippian strata (~353–326 Ma) are predominantly carbonate. The Pennsylvanian to Permian strata (~318–276 Ma) are predominantly siliciclastic, associated with the Alleghanian orogeny and the Ouachita orogeny. The Cretaceous strata (~115–66 Ma) are siliciclastic, approximately coincident with the Laramide orogeny. Lithologic variability on the order of tens of millions of years is correlated with tectonic activity in combination with climatic changes, whereas lithologic variability of shorter duration (<10 million years) may have been caused by changes in climate or sea level or both (without necessarily a major tectonic influence).

The petroleum source rocks fall into five groups according to stratigraphic occurrence. These five groups are listed as follows: (1) hypothetical source rocks of Precambrian and Cambrian shale; (2) shale within the Cambrian Eau Claire Formation; (3) Ordovician source rocks, including shale within the Ordovician Ancell Group (Dutchtown Limestone and Joachim Dolomite), shale within the Ordovician Galena Group (and equivalent strata), and shale within the Ordovician Maquoketa Group; (4) shale within the Devonian to Mississipppian New Albany Shale (and equivalent strata); and (5) Pennsylvanian coal and shale. The petroleum plays are more widely distributed throughout the stratigraphic sections than the source rocks, suggesting that there has been some migration of petroleum. However, the Precambrian to Cambrian source rocks are thought to have supplied petroleum only to Precambrian through Ordovician reservoirs, the Ordovician source rocks are thought to have supplied petroleum only to Ordovician reservoirs, and the Pennsylvanian source rocks are thought to have supplied petroleum only to Pennsylvanian reservoirs. In contrast, the Upper Devonian to lower Mississippian New Albany Shale (Group) is thought to have supplied petroleum to most reservoirs of Silurian through Pennsylvanian age. The recognition of five discrete groups of petroleum source rocks suggests that there are at least five different petroleum systems within the Illinois basin.

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REFERENCES CITED

American Association of Petroleum Geologists (AAPG), 1984, Midwestern basins and arches region correlation chart: Tulsa, Okla., American Association of Petroleum Geologists Correlation Chart Series, 1 folded sheet in jacket. (Correlation of Stratigraphic Units of North America (COSUNA) Project.)

American Association of Petroleum Geologists (AAPG), 1986, Mid-continent region correlation chart: Tulsa, Okla., American Association of Petroleum Geologists Correlation Chart Series, 1 folded sheet in jacket. (Correlation of Stratigraphic Units of North America (COSUNA) Project.)

Babcock, L.E., Robison, R.A., Rees, M.N., Peng, Shanchi, and Saltzman, M.R., 2007, The global boundary stratotype section and point (GSSP) of the Drumian Stage (Cambrian) in the Drum Mountains, Utah, USA: Episodes, v. 30, no. 2, p. 85–95.

Bergström, S.M., Chen, Xu, Gutiérrez-Marco, J.C., and Dronov, Andrei, 2008, The new chronostratigraphic classification of the Ordovician System and its relations to major regional series and stages and to $\delta^{13}C$ chemostratigraphy: Lethaia DOI:10.1111/j.1502-3931.2008.00136.x, 11 p.

Berkey, C.P., 1906, Paleogeography of St. Peter time: Geological Society of America Bulletin, v. 17, p. 229–250.

Cecil, C.B., Dulong, F.T., West, R.R., Stamm, R.G., Wardlaw, B.R., and Edgar, N.T., 2003, Climate controls on the stratigraphy of a Middle Pennsylvanian cyclothem in North America, *in* Cecil, C.B., and Edgar, N.T., eds., Climate controls on stratigraphy: SEPM (Society for Sedimentary Geology) Special Publication 77, p. 151–180.

Cecil, C.B., Brezinski, D.K., and Dulong, Frank, 2004, The Paleozoic record of changes in global climate and sea level; Central Appalachian basin, *in* Southworth, Scott, and Burton, William., eds., Geology of the National Capital Region—Field trip guidebook: U.S. Geological Survey Circular 1264, p. 77–135.

Conant, L.C., and Swanson, V.E., 1961, Chattanooga Shale and related rocks of central Tennessee and nearby areas: U.S. Geological Survey Professional Paper 357, 91 p.

Crowell, J.C., 1999, Pre-Mesozoic ice ages; Their bearing on understanding the climate system: Geological Society of America Memoir 192, 106 p.

Dennison, J.M., and Head, J.W., 1975, Sealevel variations interpreted from the Appalachian basin Silurian and Devonian: American Journal of Science, v. 275, no. 10, p. 1089–1120.

Dott, R.H., Jr., Byers, C.W., Fielder, G.W., Stenzel, S.R., and Winfree, K.E., 1986, Aeolian to marine transition in Cambro-Ordovician cratonic sheet sandstones of the northern Mississippi Valley, U.S.A.: Sedimentology, v. 33, no. 3, p. 345–367.

Drobniak, Agnieszka, Mastalerz, Maria, Rupp, John, and Eaton, Nathan, 2004, Evaluation of coalbed gas potential of the Seelyville Coal Member, Indiana, USA: International Journal of Coal Geology, v. 57, p. 265–282.

English, J.M., and Johnston, S.T., 2004, The Laramide orogeny; What were the driving forces?: International Geology Review, v. 46, p. 833–838.

Ettensohn, F.R., 1994, Tectonic control on formation and cyclicity of major Appalachian unconformities and associated stratigraphic sequences, *in* Dennison, J.M., and Ettensohn, F.R., eds., Tectonic and eustatic controls on sedimentary cycles: SEPM (Society for Sedimentary Geology) Concepts in Sedimentology and Paleontology, v. 4, p. 217–242.

Grabau, A.W., 1940, The rhythm of the ages: Peking, Henri Vetch, 561 p.

Gradstein, Felix, Ogg, James, and Smith, Alan, eds., 2004, A geologic time scale, 2004: Cambridge, U.K., Cambridge University Press, 589 p., 1 pl.

Harland, W.B., Armstrong, R.L., Cox, A.V., Craig, L.E., Smith, A.G., and Smith, D.G., 1990, A geologic time scale, 1989: Cambridge, U.K., Cambridge University Press, 263 p.

Harrison, R.W., and Litwin, R.J., 1997, Campanian coastal plain sediments in southeastern Missouri and southern Illinois—Significance to the early geologic history of the northern Mississippi embayment: Cretaceous Research, v. 18, p. 687–696.

Hass, W.H., 1956, Age and correlation of the Chattanooga Shale and the Maury Formation: U.S. Geological Survey Professional Paper 286, 47 p.

Hower, J.C., Rich, F.J., Williams, D.A., Bland, A.E., and Fiene, F.L., 1990, Cretaceous and Eocene lignite deposits, Jackson Purchase, Kentucky: International Journal of Coal Geology, v. 16, p. 239–254.

Kolata, D.R., and Nelson, W.J., 1990, Tectonic history of the Illinois basin, *in* Leighton, M.W., Kolata, D.R., Oltz, D.F., and Eidel, J.J., eds., Interior cratonic basins: American Association of Petroleum Geologists Memoir 51, p. 263–285.

Magoon, L.B., and Dow, W.G., 1994, The petroleum system, chap. 1 *of* Magoon, L.B., and Dow, W.G., eds., The petroleum system; From source to trap: American Association of Petroleum Geologists Memoir 60, p. 3–24.

Mancini, E.A., Puckett, T.M., and Tew, B.H., 1996, Integrated biostratigraphic and sequence stratigraphic framework for Upper Cretaceous strata of the eastern Gulf Coastal Plain, USA: Cretaceous Research, v. 17, p. 645–669.

Maxon, Julie, and Tikoff, Basil, 1996, Hit-and-run collision model for the Laramide orogeny, western United States: Geology, v. 24, no. 11, p. 968–972.

McIntosh, J.C., Walter, L.M., and Martini, A.M., 2002, Pleistocene recharge to midcontinent basins; Effects on salinity structure and microbial gas generation: Geochimica et Cosmochimica Acta, v. 66, p. 1681–1700.

Miller, K.G., Kominz, M.A., Browning, J.V., Wright, J.D., Mountain, G.S., Katz, M.E., Sugarman, P.J., Cramer, B.S., Christie-Blick, Nicholas, and Pekar, S.F., 2005, The Phanerozoic record of global sea-level change: Science, v. 310, p. 1293–1298.

Morse, D.G., Demir, Ilham, Moore, T.R., and Elrick, S.D., 2005, Coalbed methane research drilling in Illinois—New data [abs.], *in* Mountains of opportunity [Program with abstracts,] 2005 Eastern Section, American Association of Petroleum Geologists, 34th annual meeting, September 18–20, 2005, …, Morgantown, WV: Morgantown, West Virginia Geological and Economic Survey, p. 27–28. (Also available online at http://karl.nrcce.wvu.edu/esaapg/ESabstracts.html.)

Nelson, W.J., Trask, C.B., Jacobson, R.J., Damberger, H.H., Williamson, A.D., and Williams, D.A., 1990, Absaroka Sequence—Pennsylvanian and Permian Systems, *in* Leighton, M.W., Kolata, D.R., Oltz, D.F., and Eidel, J.J., eds., Interior cratonic basins: American Association of Petroleum Geologists Memoir 51, p. 143–164.

Olive, W.W., 1965, Geology of the Hico quadrangle, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ–332, scale 1:24,000.

Olive, W.W., and McDowell, R.C., 1986, Cretaceous and Tertiary Systems, *in* McDowell, R.C., ed., The geology of Kentucky—A text to accompany the geologic map of Kentucky: U.S. Geological Survey Professional Paper 1151–H, p. H46–H49.

Patchen, D.G., 1996, Introduction to the atlas of major Appalachian gas plays, *in* Roen, J.B., and Walker, B.J., eds., The atlas of major Appalachian gas plays: West Virginia Geological and Economic Survey Publication V–25, p. 1.

Quinlan, G.M., and Beaumont, Christopher, 1984, Appalachian thrusting, lithospheric flexure, and the Paleozoic stratigraphy of the Eastern Interior of North America: Canadian Journal of Earth Sciences, v. 21, no. 9, p. 973–996.

Ridgley, J.L., and Nuccio, V.F., 1995, Source rock potential of the lower part of the Mississippian St. Louis Limestone in south-central Indiana: U.S. Geological Survey Bulletin 2094–D, 12 p.

Shaver, R.H., Ault, C.H., Burger, A.M., Carr, D.D., Droste, J.B., Eggert, D.L., Gray, H.H., Harper, Denver, Hasenmueller, N.R., Hasenmueller, W.A., Horowitz, A.S., Hutchison, H.C., Keith, B.D., Keller, S.J., Patton, J.B., Rexroad, C.B., and Wier, C.E., 1986, Compendium of Paleozoic rock-unit stratigraphy in Indiana—A revision: Indiana Geological Survey Bulletin 59, 203 p., 2 pls. in pocket.

Sloss, L.L., 1963, Sequences in the cratonic interior of North America: Geological Society of America Bulletin, v. 74, no. 2, p. 93–114.

Sloss, L.L., 1988, Tectonic evolution of the craton in Phanerozoic time, *in* Sloss, L.L., ed., Sedimentary cover; North American craton, v. D–2 *of* The geology of North America: Boulder, Colo., Geological Society of America, p. 25–51.

Summerson, C.H., and Swann, D.H., 1970, Patterns of Devonian sand on the North American craton and their interpretation: Geological Society of America Bulletin, v. 81, no. 2, p. 469–490.

Swezey, C.S., 2002, Regional stratigraphy and petroleum systems of the Appalachian basin, North America: U.S. Geological Survey Geologic Investigations Series Map I–2768, 1 sheet. (Also available online at http://pubs.usgs.gov/imap/i-2768/.)

Swezey, C.S., 2008, Regional stratigraphy and petroleum systems of the Michigan basin, North America: U.S. Geological Survey Scientific Investigations Map SIM 2978, 1 sheet. (Also available online at http://pubs.usgs.gov/sim/2978/.)

Swezey, C.S., Hatch, J.R., Brennan, S.T., East, J.A., Repetski, J.E., and Rowan, E.L., 2007a, The U.S. Geological Survey 2007 oil and gas assessment of the Illinois basin [abs.], *in* Winning the energy trifecta; Explore, develop, sustain—Program with abstracts, 2007 Eastern Section, American Association of Petroleum Geologists …, 36th annual meeting, September 16–18, 2007, …, Lexington, Kentucky: Lexington, Kentucky Geological Survey, p. 56. (Also available online at http://karl.nrcce.wvu.edu/esaapg/ESabstracts.html.)

Swezey, C.S., Hatch, J.R., Brennan, S.T., East, J.A., Rowan, E.L., Repetski, J.E., Charpentier, R.R., Cook, T.A., Klett, T.R., Pollastro, R.M., and Schenk, C.J., 2007b, Assessment of undiscovered oil and gas resources of the Illinois basin, 2007: U.S. Geological Survey Fact Sheet 2007–3058, 2 p. (Also available online at http://pubs.usgs.gov/fs/2007/3058/.)

Tedesco, S.A., 2003, Positive factors dominate negatives for Illinois basin coalbed methane: Oil and Gas Journal, v. 101, no. 13, p. 28–32.

Thompson, T.L., 1986, Paleozoic succession in Missouri, Part 4—Mississippian System: Missouri Geological Survey Report of Investigations RI–70, 189 p.

Tissue, J.S., and Langenheim, R.L., Jr., 1979, Paleoenvironments of Middle Devonian sandstones of upper Mississippi Valley: American Association of Petroleum Geologists Bulletin, v. 63, no. 3, p. 542.

Van Schmus, W.R., Bickford, M.E., and Turek, A., 1996, Proterozoic geology of the east-central midcontinent basement, *in* van der Pluijm, B.A., and Catacosinos, P.A., eds., Basement and basins of eastern North America: Geological Society of America Special Paper 308, p. 7–32.

Weems, R.E., and Olsen, P.E., 1997, Synthesis and revision of groups within the Newark Supergroup, eastern North America: Geological Society of America Bulletin, v. 109, p. 195–209.

Wheeler, H.E., 1963, Post-Sauk and pre-Absaroka Paleozoic stratigraphic patterns in North America: American Association of Petroleum Geologists Bulletin, v. 47, no. 8, p. 1497–1526.

Willman, H.B., Atherton, Elwood, Buschbach, T.C., Collinson, Charles, Frye, J.C., Hopkins, M.E., Linebach, J.A., and Simon, J.A., 1975, Handbook of Illinois stratigraphy: Illinois State Geological Survey Bulletin 95, 261 p.

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