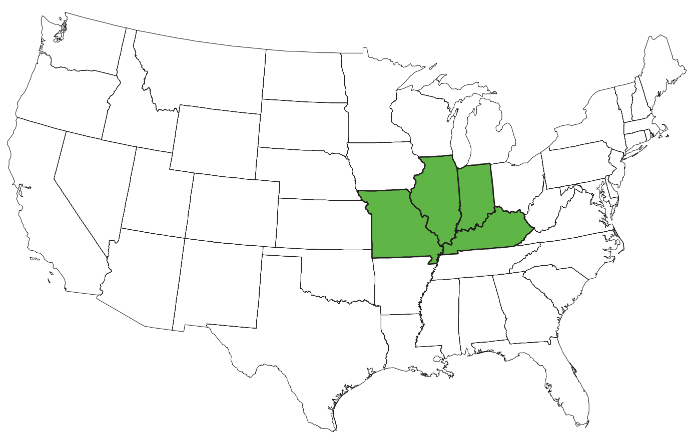
Illinois Map 23

Geological and Geophysical Maps of the Illinois Basin–Ozark Dome Region

Compiled by Stephen Marshak, Timothy H. Larson, and Curtis C. Abert

2016



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Introduction

This map series was initially envisioned as a means to provide a visual context for discussions associated with the National Science Foundation EarthScope Workshop entitled *Tectonic Targets for EarthScope in the Mid-continent*, held on April 11–13, 2010, in Urbana, Illinois (Stephen Marshak, lead convener). Participants were sufficiently interested in the maps, and therefore we decided to publish them.

The 12 maps in this series form a set that spans the four-state region of Missouri, Illinois, Indiana, and Kentucky. We refer to the set as the MIINK series. Although we knew of excellent maps in each of these states, few, if any, were available that stitched together information for the entire region. We have used existing local work to compile regional maps that provide a broader context for research on the tectonics of the central Midcontinent. This set consists of three types of maps: base maps, structure-contour maps, and thematic maps. They are intended to be used together as map layers in regional geological investigations. Geographic points of reference and cartographic labels have been kept to a minimum to facilitate the overlay process. All maps include a base map of state and county outlines for internal reference.

To facilitate descriptions and illustrate possible use of the maps, we have reproduced reduced-size versions in the text. Features of interest are not placed precisely on these smaller images—they have been annotated for illustrative purposes only.

Maps 1 to 4 of the MIINK series are base maps. They illustrate ground surface and bedrock topography and geology and provide a reference for tectonic studies of the region.

Maps 5 to 8 are structure-contour maps on four key Paleozoic horizons. We produced these maps to help illustrate the timing of movement on structures in the Midcontinent. These maps show how the shape of the Illinois Basin has changed through time. Initially, we attempted to produce isopach maps showing the thickness of the intervals between the horizons, but this was difficult because the horizons are not continuous in space across the entire region. Isopach maps of parts of the region, especially the Illinois Basin itself, could be constructed from the layers, but we have left that project for future work.

Maps 9 to 12 are thematic maps. These maps are particularly useful as overlays on the structure-contour or geologic maps to provide insight into the underlying tectonic processes in the region.

Base Maps

Map 1—Land-Surface Topography
This map is a digital elevation model at 3× vertical exaggeration that displays the present-day ground surface elevation in shaded relief (Figure 1). It shows standard color representations for elevation. Several key features are prominent on the map:

- Topographic manifestations of subsurface structure, for example, the contrast between (1) the highland of the Ozark Plateau and (2) the lowland of the Illinois Basin, (3) the highland associated with the "crustal bridge" separating the Reelfoot Rift from (4) the southwestern end of the Rome Trough (see also Map 8), (5) the termination of the Mississippi Embayment (see also Map 4), and the abruptness of the borders of the Ozark Plateau. Compare these topographic expressions with the subsurface structures on Maps 5 through 8.

- Pleistocene landscape features, such as (6) the Wisconsin Episode moraines of Illinois and Indiana. These and other Pleistocene features are shown on Map 4.

- The major drainages of the Midcontinent (Missouri, Mississippi, Ohio, Illinois) and their relation to regional-scale topographic features.

Map 2—Bedrock Topography
This map is a digital elevation model of the bedrock surface at 3× vertical exaggeration (Figure 2). In regions that have a cover of Pleistocene glacial drift, the map uses the surface of the unconformity between the drift and the bedrock surface. In places outside of the cover of Pleistocene glacial drift, it corresponds to a subdued version of the ground surface or to the ground surface itself. The map emphasizes the effect of the Pleistocene glaciations (see Map 3), which completely altered the drainage patterns in Illinois and Indiana. The apparently smoother surface in Missouri is an artifact of the lower data density in the map coverage from Missouri. The bedrock surface in Missouri is actually just as rugged as that in the other three states.

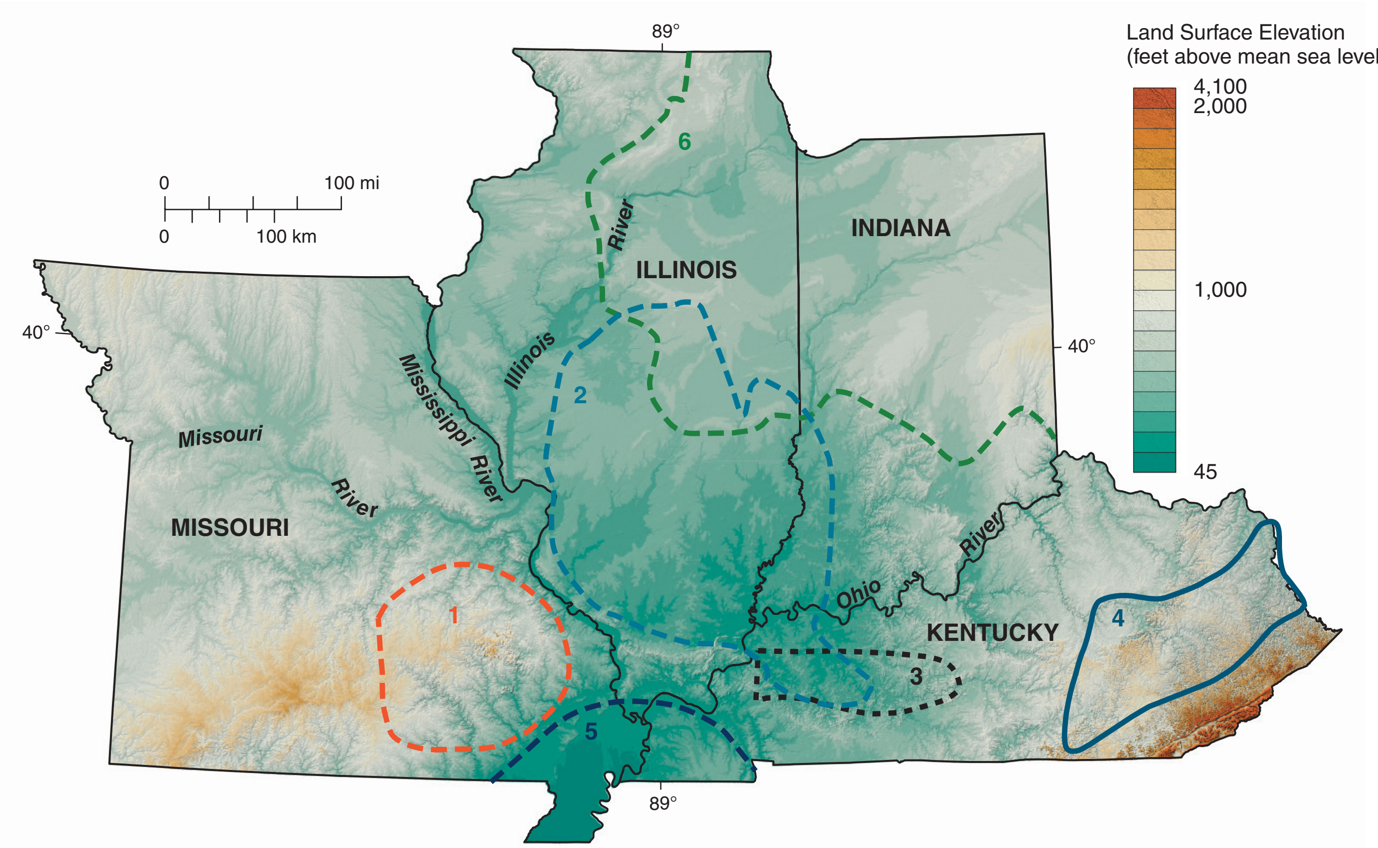

Figure 1 Land-surface topography. Numbered regions are (1) the highland of the Ozark Plateau and (2) the lowland of the Illinois Basin, (3) the highland associated with the "crustal bridge" separating the Reelfoot Rift from (4) the southwestern end of the Rome Trough (see also Map 8), (5) the termination of the Mississippi Embayment, and (6) the terminal Wisconsin Episode moraines.

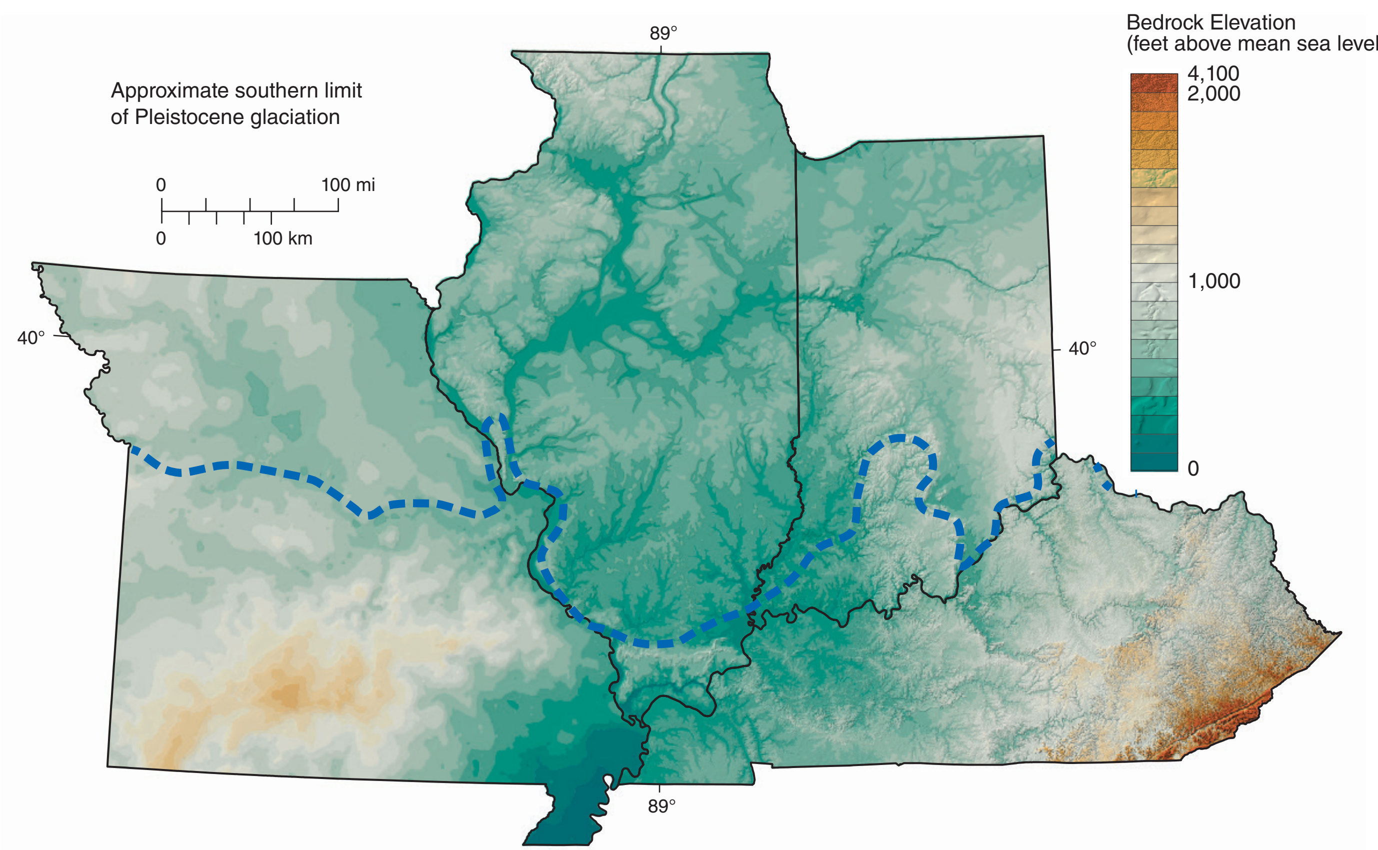

Figure 2 Bedrock topography. Source of map: U.S. Geological Survey.

Map 3—Surficial Geology with Shaded Relief
This map shows the distribution and character of Pleistocene glacial sediment and Pleistocene to recent river alluvium in the MIINK area (Figure 3). Only areas that have substantial thicknesses of sediment overlying bedrock are illustrated. Most of Kentucky and Missouri south of the Missouri River is mapped as colluvium, residuum, or saprolite, which is shown in gray on this map. Glacial deposits are distinguished by age according to the traditional land-based chronology of glaciations.

Map 4—Bedrock Geology with Bedrock Topography
This map shows the distribution of bedrock units within the map area (Figure 4). Units are defined by stratigraphic age and are divided along stage boundaries. Comparable with our usage for Missouri, Kentucky, and Indiana, we have included Quaternary units in river valleys on this map even though Quaternary sediments are not bedrock materials within any of these states. Quaternary sediments in Illinois are shown on Map 3 rather than Map 4. However, Quaternary sediments of the northern extension of the Mississippi Embayment (southeast Missouri, southernmost Illinois, and western Kentucky) are shown on Map 4. Tertiary and Cretaceous rocks are also mapped along the northern fringe of the Mississippi Embayment. North of the Mississippi Embayment, the bedrock is Paleozoic in age except for some Precambrian rocks in the Ozark Plateau. The regional pattern of the Paleozoic units delimits the underlying structural features. From west to east, the youngest sediments of Pennsylvanian age occupy structural lows that alternate with older sediments in structurally higher regions. This structural pattern becomes clear in the structure-contour maps (Maps 5 to 8).

Production of this map required us to correlate stratigraphic units across state boundaries, a challenging task considering that different states do not necessarily use the same map units. On the map, the geological data are placed on the shaded relief bedrock topography.

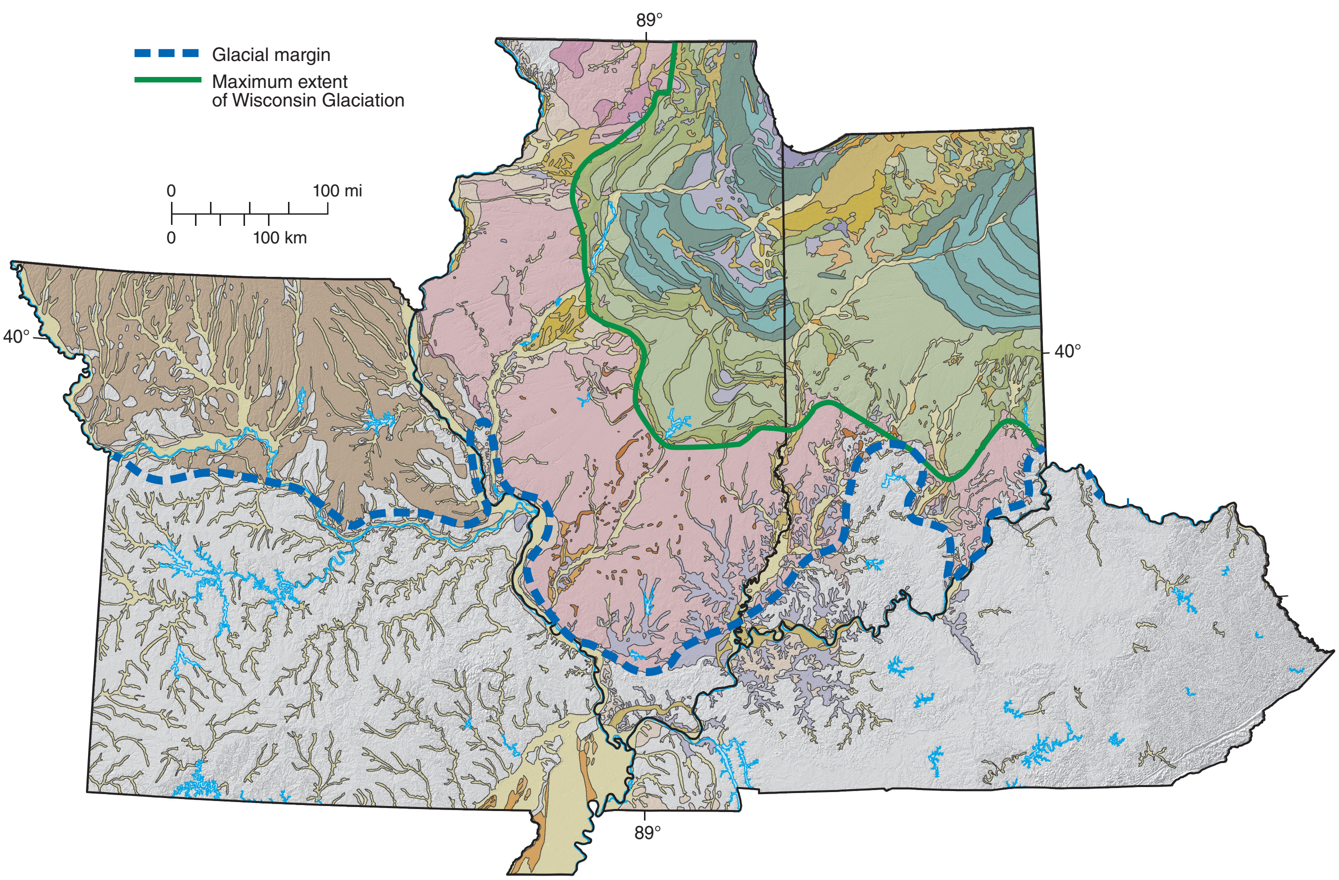

Figure 3 Surficial geology with shaded relief (showing glacial and alluvial deposits).

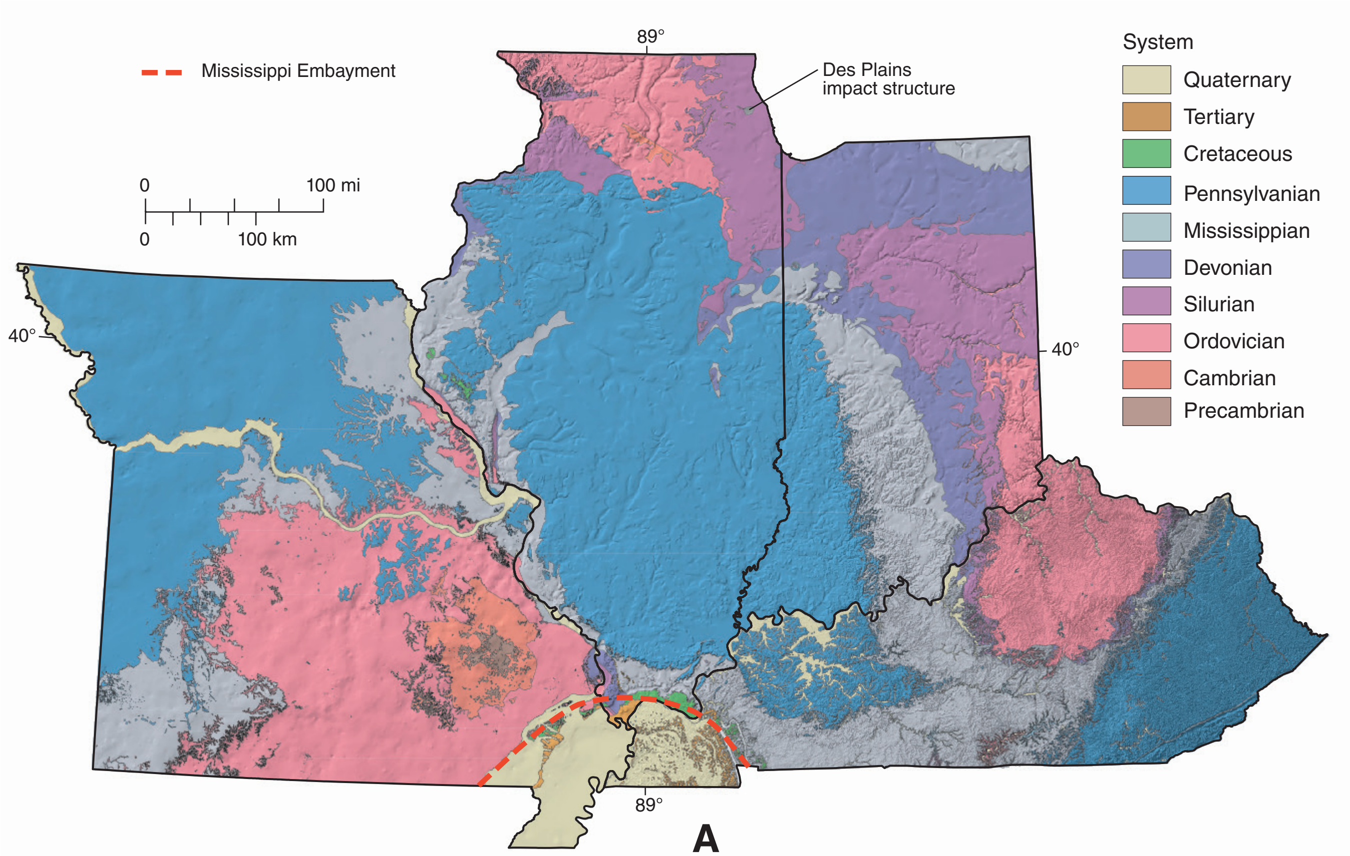

Figure 4 Bedrock geology with bedrock topography.

Structure-Contour Maps

The structure-contour maps are drawn on four key Paleozoic horizons (Figure 5A). We show contour maps overlain on graduated-color hill-shaded maps of the structure. Hill shading is intended to aid in visualizing the structural features, but confuses the color gradations. To clarify the actual depths portrayed, we include the labeled contours. However, in this report we include only the shaded relief versions.

Map 5—Structure Contours of the Top of the Pennsylvanian Springfield Coal and Bevier Coal (Missouri)

Map 5 shows the variation in elevation of the top of the Springfield Coal, a Pennsylvanian stratigraphic marker horizon in the Illinois Basin (Figure 5B). The purpose of the map is to highlight syn- and post-Pennsylvanian structural features of the map area. The variation in elevation reflects differential subsidence in the region. It also reflects intracratonic deformation because the development of folds and the displacement on faults in the map area (see Map 11) cause local variation in the elevation of the Springfield Coal. It is evident from the map that the coal is deeper over the depocenter of the Illinois Basin, so the basin was actively subsiding during deposition of the Springfield Coal. In addition, displacements of structures in the La Salle Anticlinorium were active at the time because the coal is significantly shallower over the top of the La Salle Anticlinorium.

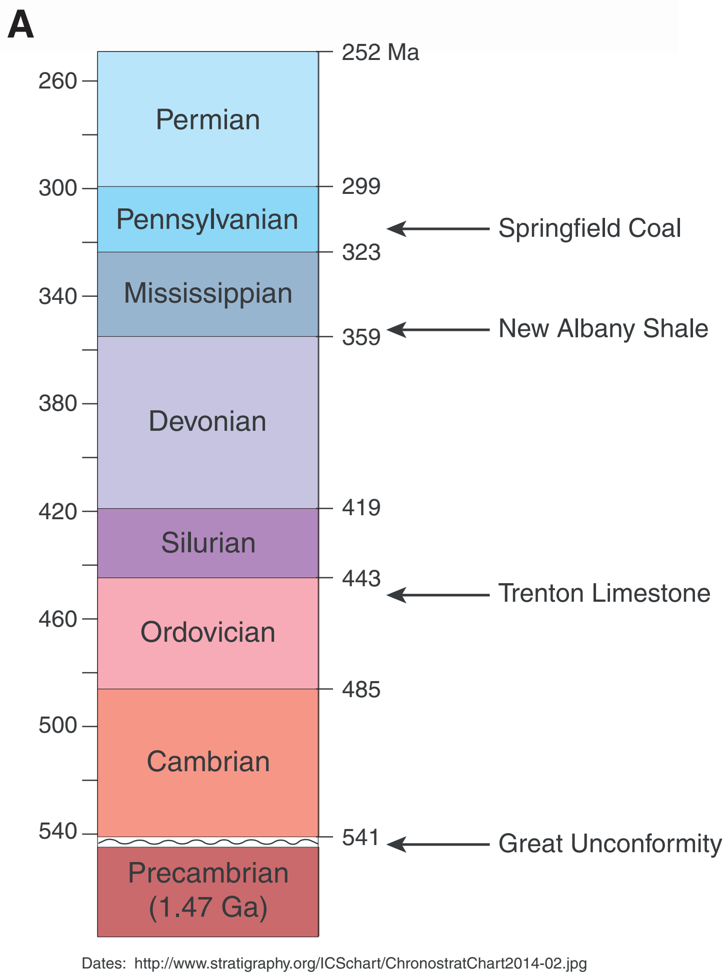

Figure 5 (A) Simplified stratigraphy of the MIINK area showing the age and relative stratigraphic levels of the marker horizons that were contoured. *Figure continues on page 5.*

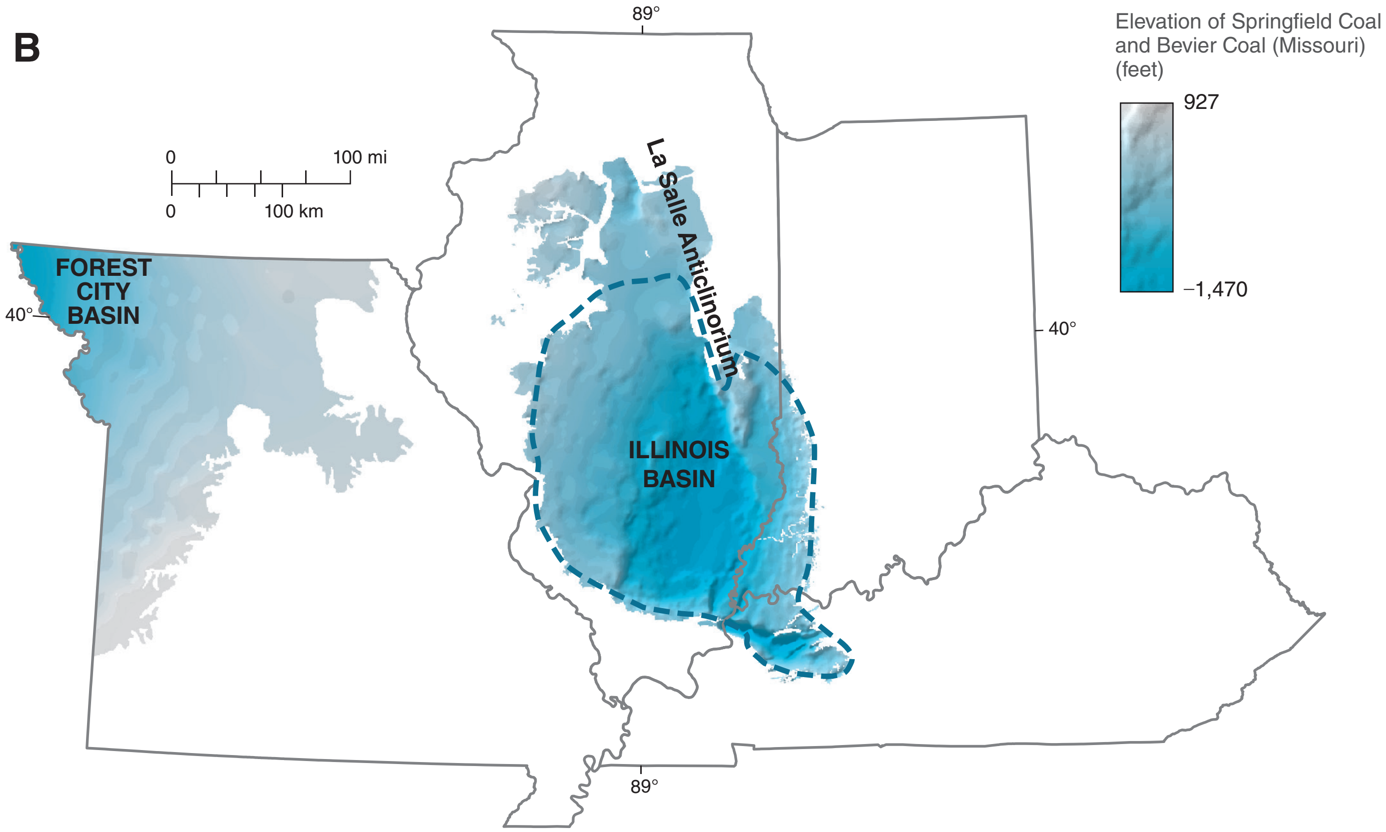

Figure 5 (*continued*) (B) Elevation of the Pennsylvanian Springfield Coal and Bevier Coal (Missouri).

The Springfield Coal is an Illinois Basin deposit. We were not able to obtain a map of its equivalent in Missouri, the Summit Coal, at this scale. To illustrate the Pennsylvanian structures in Missouri, we contoured the Bevier Coal, an extensive Desmoinesian deposit slightly older than the Springfield Coal. The color of this map was chosen to coincide with the color of the Pennsylvanian Stage rocks depicted on the *Bedrock Geology with Bedrock Topography* map (Map 4).

Map 6—Structure Contours of the Top of the Mississippian-Devonian New Albany Shale and Correlatives

This map shows the variation in elevation of the top of a Devonian-Mississippian marker horizon, the New Albany Shale (Figure 6). This unit may be of increasing significance in the near future because of its potential as gas shale. The New Albany Shale has been eroded from the Ozark Dome, Wisconsin Arch, and Cincinnati Arch but is preserved throughout the Illinois Basin. Its depth is clearly affected by structural features such as the La Salle Anticlinorium and the Rough Creek Graben. For Missouri, we used an available map of the structure on the base of the Burlington Limestone and the top of the Chouteau Limestone, which are both slightly higher in the Mississippian stratigraphy than the top of the New Albany Shale equivalents. The color of this map coincides with the color of the Devonian System rocks depicted on the *Bedrock Geology with Bedrock Topography* map (Map 4).

Map 7—Structure Contours of the Top of the Ordovician Trenton Limestone (or Equivalent)

This map shows the variation in elevation of the top of the Trenton Limestone, a unit deposited near the end of the Ordovician (Figure 7). The Trenton is the deepest sedimentary unit contoured. Its elevation clearly shows the shape of the Illinois Basin, the Rough Creek Graben, and the Cincinnati Arch. The color of this map coincides with the color of the Ordovician System rocks depicted on the *Bedrock Geology with Bedrock Topography* map (Map 4). Map 7 is from Nelson (1995), who reproduced Collinson et al. (1988). Collinson et al. (1988) extracted the Trenton Limestone contours from the compilation of Cohee and others (1962).

Map 8—Structure Contours of the Top of the Precambrian

This map shows the elevation of the top of the basement (i.e., the “Great Unconformity” at the base of the Cambrian and the top of the Precambrian; Figure 8). It has been shaded and colored to emphasize the shape of regional-scale epeirogenic structures. The most striking feature of the map is the 25,000 ft (7,600 m) of structural relief between the Precambrian outcrops of the Ozark Plateau and the Illinois Basin. East of the Illinois Basin in central Kentucky, a narrow “bridge” of basement upland lies between the Rough Creek Graben and the southern end of the Rome Trough.

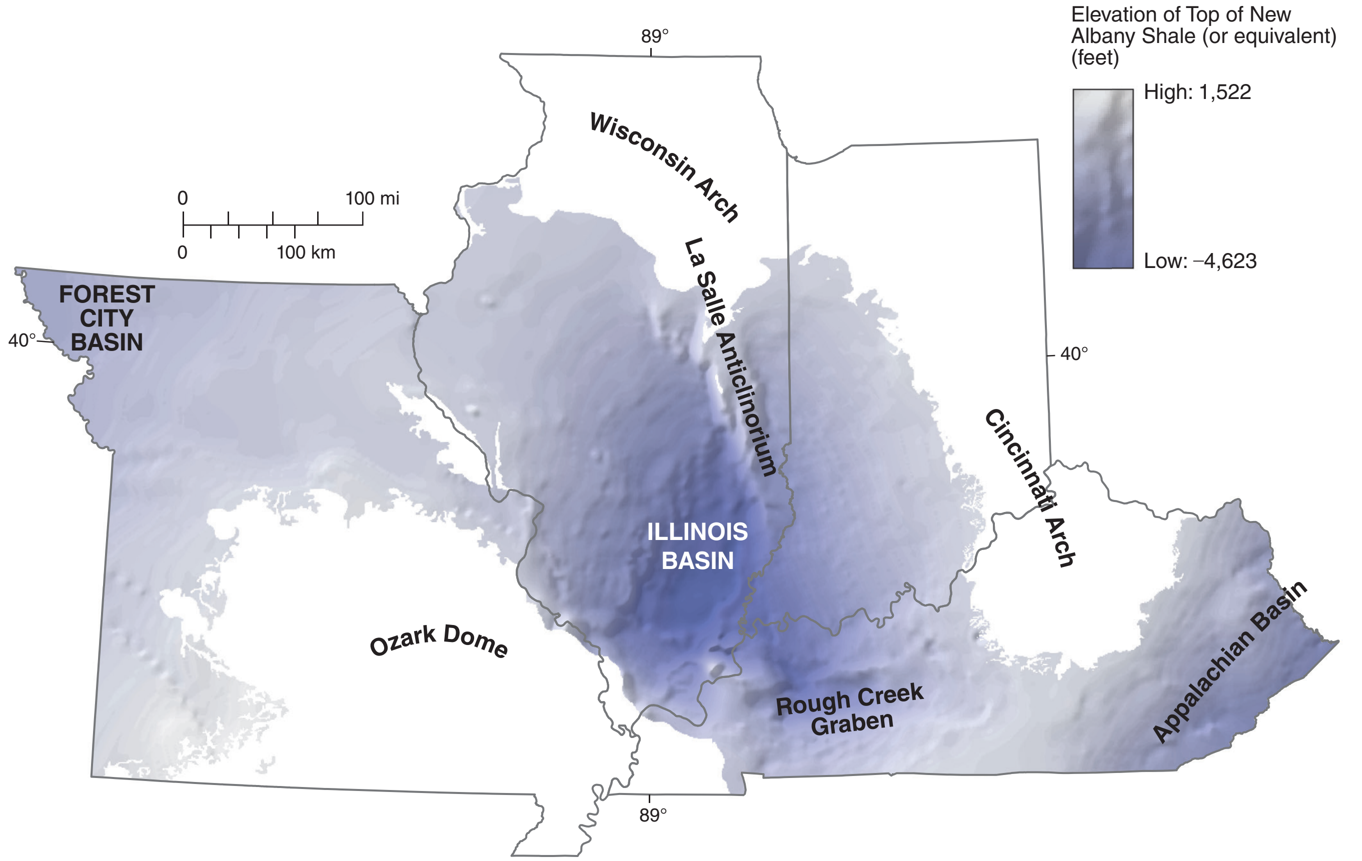

Figure 6 Elevation of the top of the Mississippian-Devonian New Albany Shale and correlatives.

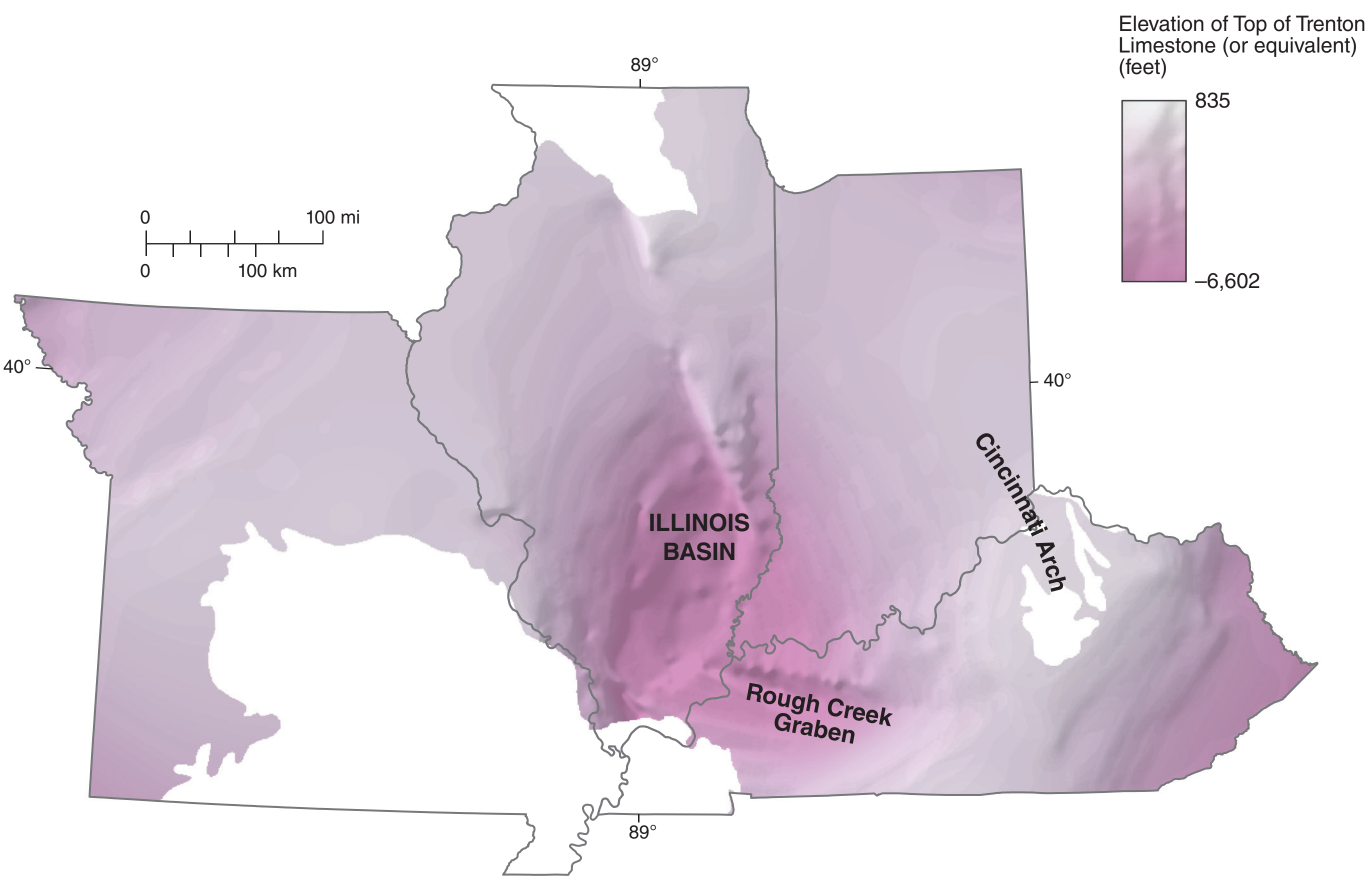

Figure 7 Elevation of the top of the Ordovician Trenton Limestone (or equivalent).

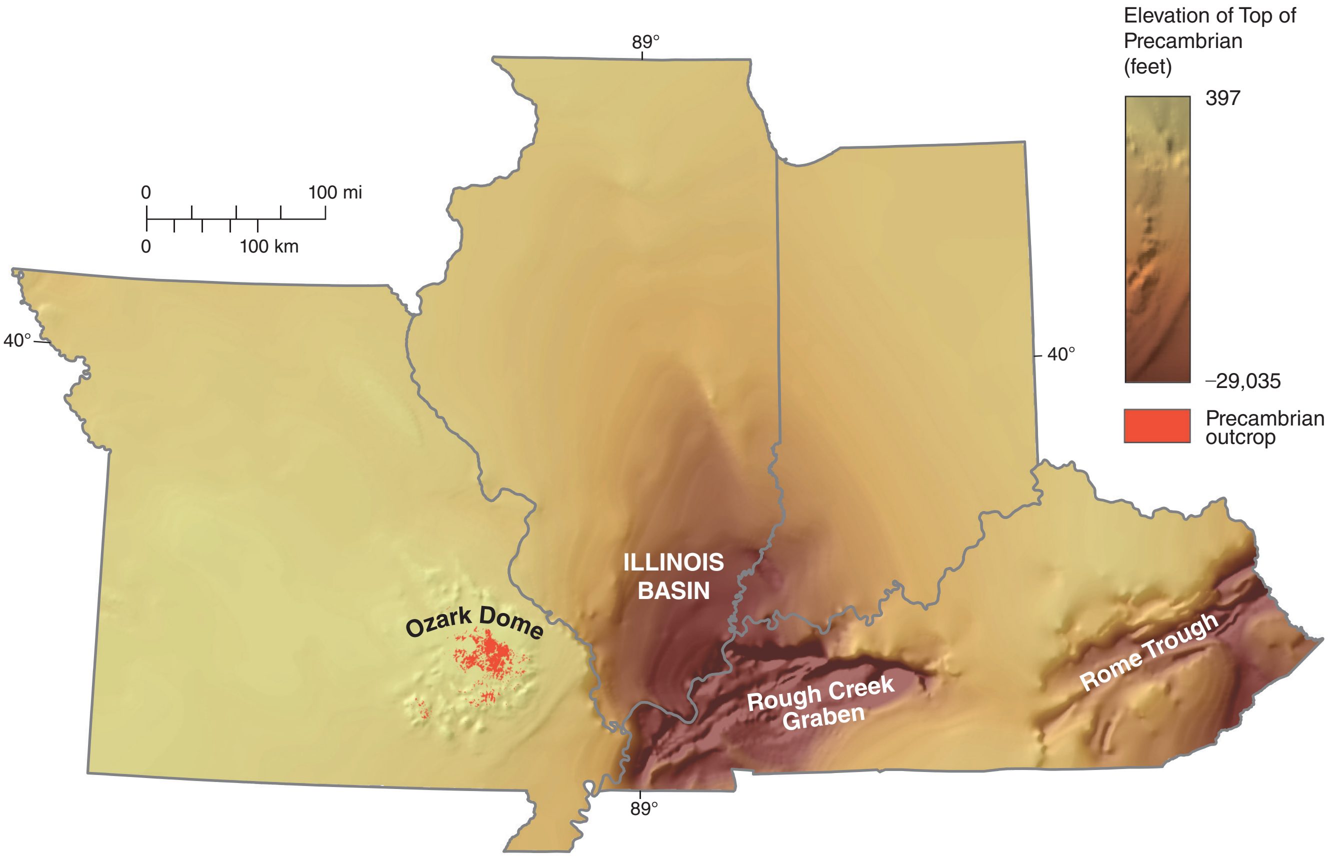

Figure 8 Elevation of the top of the Precambrian.

Thematic Maps

Map 9—Isostatic Gravity Anomaly
This map provides a subset of data made available by the U.S. Geological Survey (USGS) that displays the gravity anomaly data for the MIINK study area (Figure 9). As a large, massive body, the earth has a strong gravitational field. Sensitive instruments can measure minute variations in the gravitational field caused by variations in latitude, elevation, and material density. These variations, termed gravity anomalies, are related to heterogeneities within the crust, mantle, or both. Among the various types of gravity anomaly maps, the one displayed here is an isostatic anomaly map, in which the anomalies are assumed to result from isostatic compensation of the topographic loads of upper crustal and sedimentary features. Overlays of this map on the structure-contour maps (Maps 5 to 8) provide insight into the structural features and rock types in the region.

Map 10—Magnetic Anomaly
This map displays the magnetic anomaly data for the MIINK study area (Figure 10). Magnetic anomaly maps for large areas, such as the MIINK study area, are calculated by finding the difference between measured magnetic properties (usually from airborne surveys) and theoretical models of the earth's magnetic field. These maps represent the magnetic field associated with magnetic minerals in crustal rocks. Iron-rich igneous rocks have higher magnetic signatures than do sedimentary rocks or iron-poor igneous rocks. Of particular note is a prominent anomaly that traverses southern Illinois and corresponds to significant fault trends in the area (compare with Map 11) and known instances of igneous intrusions into the sedimentary layers. When used in conjunction with gravity anomaly maps (Map 9), magnetic anomalies provide insight into the character of basement rocks.

Map 11—Fault and Fold Traces
This map displays digitized traces of faults and folds that have been mapped in the MIINK study area (Figure 11). It is intended to be used in conjunction with other maps in the series to provide insight into the structure of the region. As such, we have avoided using labels on the map. Please see the original map sources for further details on individual features. Southeastern-most Missouri and western-most Kentucky lack data because Mesozoic and Cenozoic strata of the Mississippi Embayment hide the bedrock structure (see also Map 3). The pattern displayed by the map emphasizes the La Salle Anticlinorium running along the eastern flank of the Illinois Basin, the array of northwest-trending faults traversing Missouri, and the chain of faults reflecting the Rough Creek Graben and the Rome Trough (see also Map 8). Many faults appear to terminate abruptly in the south-central area of the map, but more likely they continue in the subsurface but are covered by younger sediment of the Mississippi Embayment.

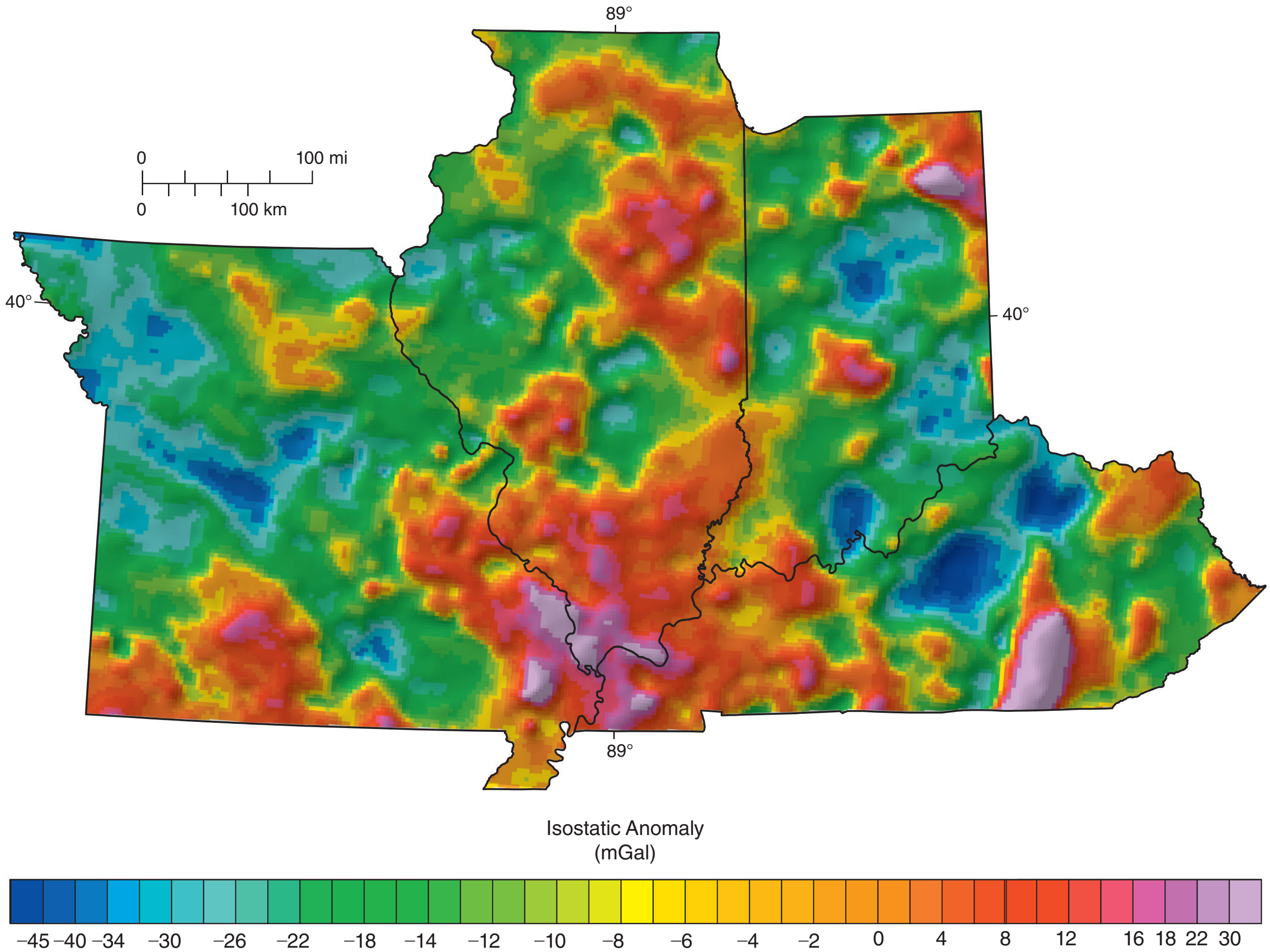

Figure 9 Isostatic gravity anomaly.

Map 12—Earthquake Epicenters 1804–2014
This map provides the locations of epicenters and sizes of earthquakes within the MIINK study area (Figure 12). It displays the activity of the New Madrid Seismic Zone, the Wabash Valley Seismic Zone, and the East Tennessee Seismic Zone, and it reveals clusters of activity in other areas, such as in northern Illinois and along the northeastern boundary of the Ozark Plateau. Comparison of this map with the top-of-basement structure-contour map (Map 8) and the fault and fold map (Map 11) reveals relationships between seismicity and structure that might otherwise be overlooked.

Several earthquake catalogs are available for use. We have chosen to use the Advanced National Seismic System earthquake catalog of the USGS for earthquakes since 1972. This catalog is robust throughout the entire study area for earthquakes greater than a magnitude of 2.0. We did not attempt to reconcile this catalog with regional catalogs, even though they may be more complete for different parts of the area. For earthquakes before 1973, we used the catalog compiled by Stover et al. (1984) with a low-end cutoff magnitude of 2.5. This cutoff is approximately the threshold for accurately documenting felt earthquakes.

Methods

These maps were compiled from existing data and are presented in a standard four-state format. Most of the data were compiled from statewide data and merged into our larger four-state format. We made minimal efforts to match data across state lines, preferring instead to concentrate on the overall picture of the regional trend. In other instances, we clipped larger data sets to fit our regional map template.

Map 1—Land Surface Topography
The elevation data were obtained from the National Elevation Dataset (NED), now available at *The National Map* (http://nationalmap.gov/), and show the terrain at a resolution of 100 meters. The NED is a raster product assembled by the USGS and is designed to provide national elevation data in a seamless form with a consistent datum, elevation unit, and projection. This data set was derived from NED data released in October 2012.

The shaded relief map was created by artificially illuminating the elevation surface from a light source located at 315 degrees azimuth and 45 degrees above the horizon. A 3× vertical exaggeration was applied to enhance the surface features.

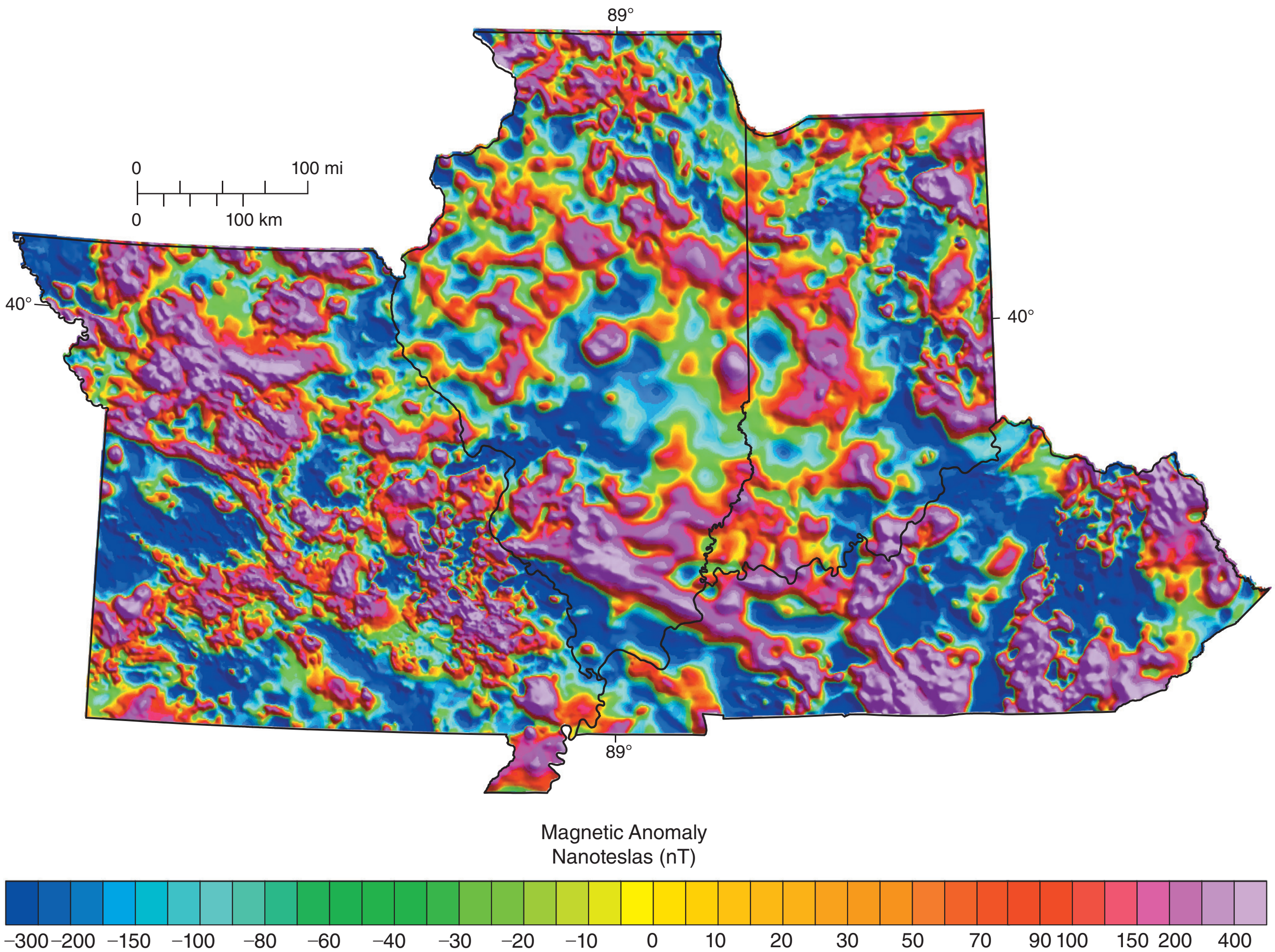

Figure 10 Magnetic anomaly.

Map 2—Bedrock Topography
This map was created in July 2009 with the Topo to Raster tool in ArcGIS by using the bedrock topographic contours of Missouri (Missouri Department of Natural Resources, 2006, ftp://msdis.missouri.edu/pub/state/st_top_rock_elev.zip), Illinois (Herzog et al. 1994, GIS Database ISDB_BEDGEO.IL_Bedrock_Topography_1994_Ln, http://www.isgs.illinois.edu/nsdihome/webdocs/st-geolb.html), and Indiana (Gray 2003, line shapefile BEDROCK_TOPOGRAPHY_MM36_IN, http://inmap.indiana.edu/dload_page/geology.html).

A bedrock topography map was not available for Kentucky because in that state, bedrock is either at or very near the land surface. Therefore, surface elevations for Kentucky were derived from the Shuttle Radar Topography Mission (SRTM), a cooperative project among the National Aeronautics and Space Administration, the National Geospatial Intelligence Agency, the German Aerospace Center, and the Italian Space Agency. Data were downloaded in July 2009 and are currently available from https://lta.cr.usgs.gov/SRTM.

A shaded-relief map was then created by artificially illuminating the elevation surface from a light source located at 315 degrees azimuth and 45 degrees above the horizon. A 5× vertical exaggeration was applied to enhance the features of the bedrock surface.

Map 3—Surficial Geology with Shaded Relief
This map was created in March 2010 by extracting the four-state area from Fullerton et al. (2003, http://pubs.usgs.gov/imap/i-2789). The shaded relief map from Map 1 was included.

Map 4—Bedrock Geology with Bedrock Topography
This map was created in June 2009 by simplifying the more detailed statewide geologic maps from the Missouri Department of Natural Resources (1979, ftp://msdis.missouri.edu/pub/state/st_geol.e00.gz), McDowell et al. (1981, http://www.uky.edu/KGS/gis/geology.htm), Gray et al. (1987, http://inmap.indiana.edu/dload_page/geology.html, polygon shapefile BEDROCK_GEOL_MM48_IN), Noger (1988, http://www.uky.edu/KGS/gis/geology.htm), and Kolata (2005, GISDB_BEDGEO.IL_Bedrock_Geology_500K_2005, http://www.isgs.illinois.edu/nsdihome/webdocs/st-geolb.html). Only system-level geology was consistent across the four-state area. The shaded-relief map of the bedrock surface in Map 2 was included.

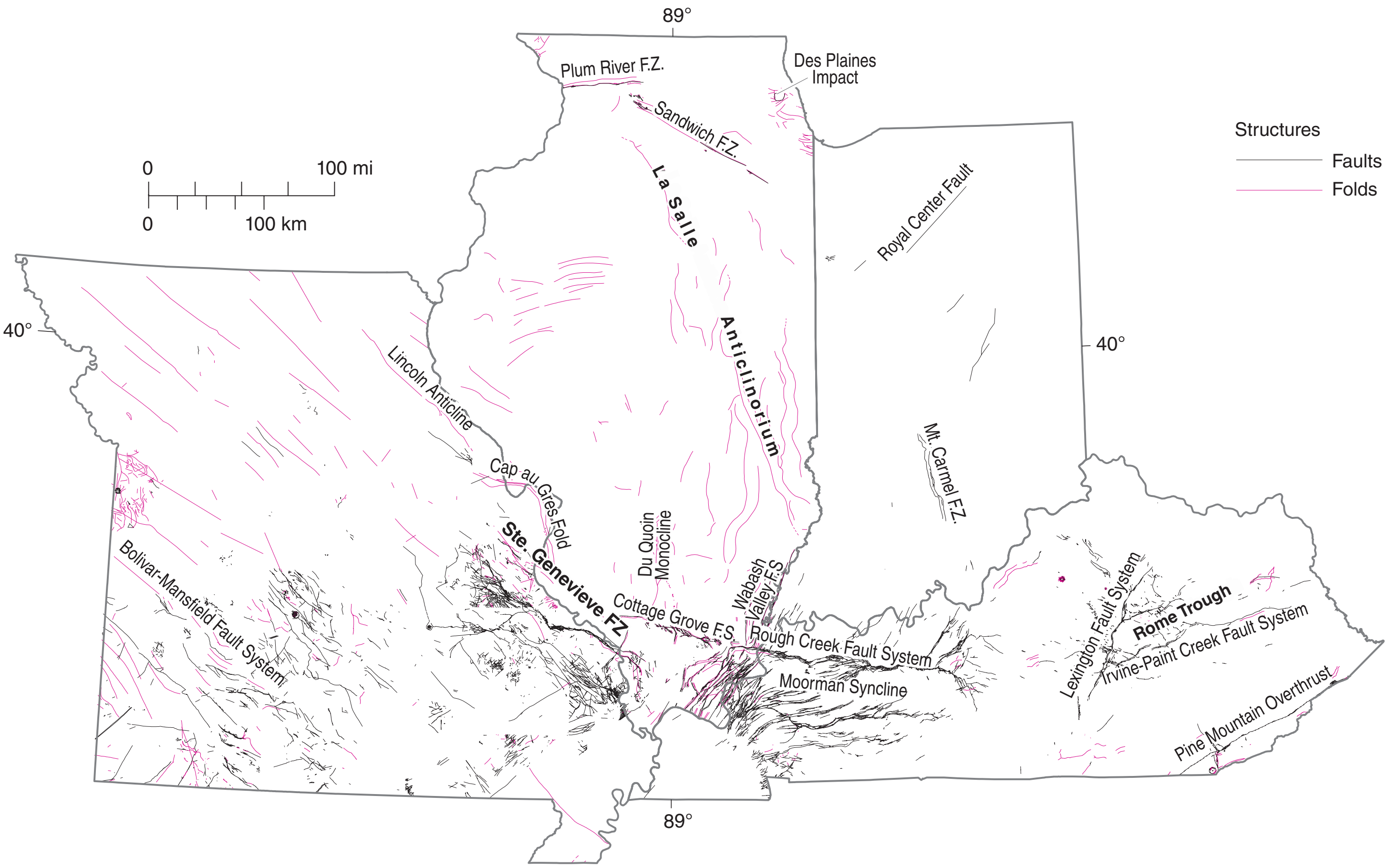

Figure 11 Fault (black) and fold (magenta) traces.

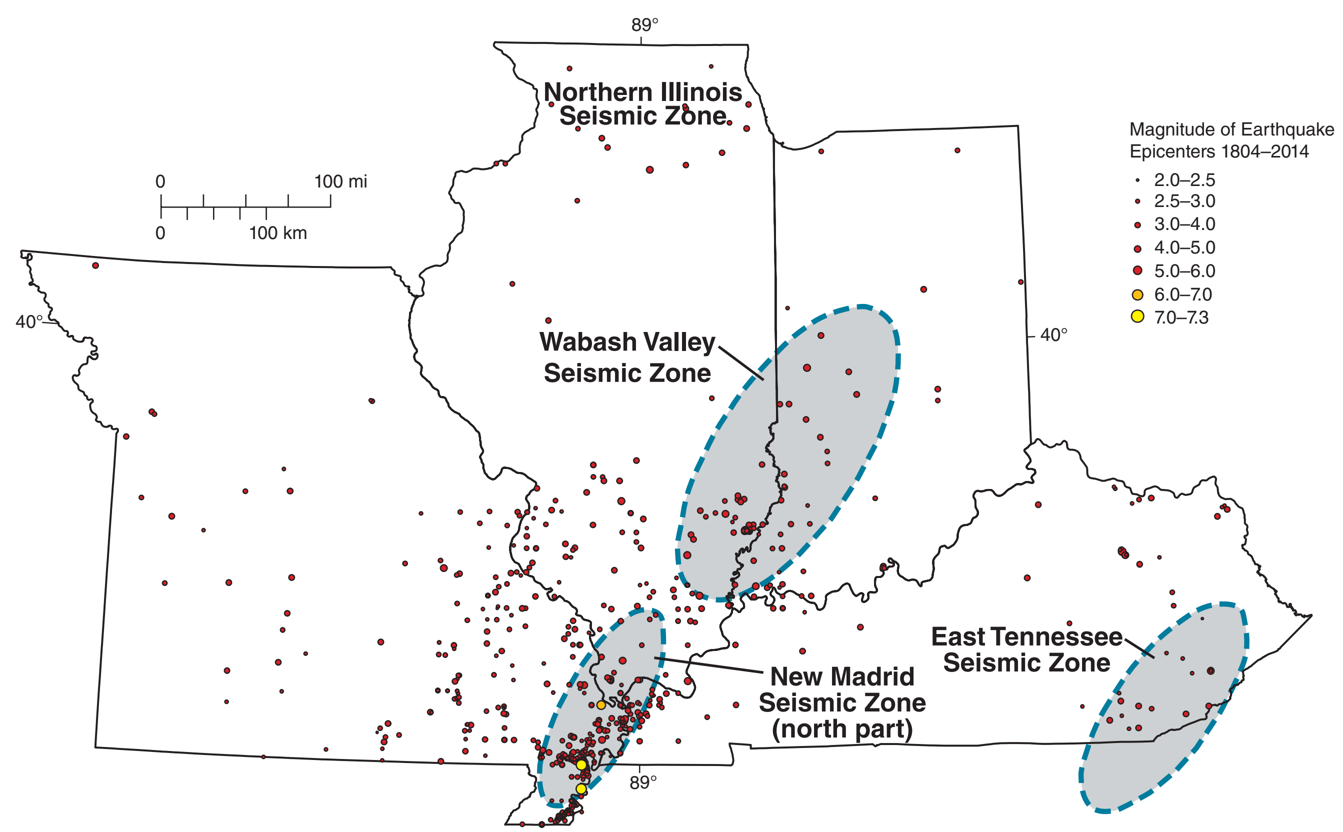

Figure 12 Earthquake epicenters (superimposed on a land-surface digital elevation model).

Map 5—Structure Contours of the Top of the Pennsylvanian Springfield Coal and Bevier Coal (Missouri)
This map was created in two parts. A published raster surface of the Springfield Coal for the Illinois Basin (USGS Central Region Energy Resources Team 2002) was clipped to the extent of the Springfield Coal in Illinois, Indiana, and Kentucky. Because the Springfield Coal is not present in Missouri, we digitized a map of the surface of the Bevier Coal (Hinds and Greene 1915), which has a similar stratigraphic position in Missouri. Point locations were converted to an ArcGIS shapefile. A raster surface was then created with the Topo to Raster tool and clipped to the extent of the Bevier Coal. The raster for the Bevier Coal was then merged with the raster of the Springfield Coal in the Illinois Basin. Finally, a shaded relief map of the combined raster surface was created by artificially illuminating the elevation surface from a light source located at 315 degrees azimuth and 45 degrees above the horizon.

Map 6—Structure Contours of the Top of the Mississippian-Devonian New Albany Shale and Correlatives
This map was created from preexisting digital contour data for Kentucky (Kentucky Geological Survey 1982) and the Illinois Basin (Morse et al. 2000) and from contours digitized from a scanned paper map of Missouri (Bohm and Palmer 1981). The paper map was scanned, and the resulting image was georeferenced in ArcGIS to the Universal Transverse Mercator (UTM) Zone 16 North American Datum (NAD) 1983 coordinate system. We then used the Topo to Raster tool in ArcGIS to create a raster surface for the four-state study area and created a shaded relief map by artificially illuminating the elevation surface from a light source located at 315 degrees azimuth and 45 degrees above the horizon. The surface and shaded relief rasters were then clipped to the extent of the unit.

Map 7—Structure Contours of the Top of the Ordovician Trenton Limestone (or Equivalent)
This map was created from contour lines digitized from the regional paper map of the top of the Trenton Limestone or equivalents in June 2009 (Nelson 1995, Figure 1). The map was scanned, and the result- ing image was georeferenced in ArcGIS to the UTM Zone 16 NAD 1983 coordinate system. The Topo to Raster tool in ArcGIS was then used to create a raster surface for the four-state study area, and a shaded relief map was created by artificially illuminating the elevation surface from a light source located at 315 degrees azimuth and 45 degrees above the horizon. The surface and shaded relief rasters were then clipped to the extent of the unit.

Map 8—Structure Contours of the Top of the Precambrian
This map was created from existing digital contour lines for Illinois and Indiana (Collinson et al. 1988) and Kentucky (Solis et al. 2005) and from contour lines digitized from a paper map of Missouri (Kisvarsanyi 1984). The paper map was scanned, the resulting image was georeferenced in ArcGIS to the UTM Zone 16 NAD 1983 coordinate system, and contours and outcrop areas were digitized. Contours for all four states were used to create a raster surface for the four-state study area with the Topo to Raster tool in ArcGIS. A shaded relief map was created by artificially illuminating the elevation surface from a light source located at 315 degrees azimuth and 45 degrees above the horizon. The surface and shaded relief rasters were then clipped to the extent of the unit.

Map 9—Isostatic Gravity Anomaly
A raster (Esri grid) data set containing isostatic anomaly data for the conterminous United States was downloaded in May 2015 from the Mineral Resources On-Line Spatial Data of the USGS (Kucks 1999, http://mrdata.usgs.gov/geophysics/gravity.html). The data were originally published by Phillips et al. (1993, ftp://ftpext.usgs.gov/pub/cr/co/denver/musette/pub/GEOPHYSICAL_DATA/cdrom_DDS-9). The grid cell size is 4,000 × 4,000 meters. ArcGIS software was used to generate isostatic anomaly contours for the four-state study area at 5-milligal (mGal) intervals. A smoothed shaded relief overlay was created to better visualize the highs and lows in the data set. For this step, we used the ArcGIS Topo to Raster tool to generate a new raster surface from the contours. The new surface was then used to create the relief surface using the Hillshade tool.

Map 10—Magnetic Anomaly
Data for this map were downloaded in March 2010 from the source website (Bankey et al. 2002, http://mrdata.usgs.gov/ geophysics/aeromag.html). ArcGIS was then used to clip the map to the four-state area. The raster data cell size is approximately 1,026 × 1,026 meters.

Map 11—Fault and Fold Traces
Data for this map were downloaded in June 2009 from the various state GIS websites or the ISGS GIS database and compiled into a single map. Kentucky sources include the Kentucky Geological Survey (2008, http://www.uky.edu/KGS/gis/geology.htm), McDowell et al. (1981, http://www.uky.edu/KGS/gis/geology.htm), and Noger (1988, http://www.uky.edu/KGS/gis/geology.htm). Missouri fault and fold data were obtained from the Missouri Department of Natural Resources (2006, http://msdis.missouri.edu). The Illinois data were drawn from Nelson (1995) in June 2009 (http://www.isgs.uiuc.edu/nsdihome/browse/statewide/zips/IL_Struct_Feat_Clines_1995_Ln.zip). The Indiana data were downloaded in June 2009 as a shapefile showing the locations of known structural features in Indiana (Indiana Geological Survey 1971, http://igs.indiana.edu/arcims/statewide/download.html, line shapefile STRUCTURAL_FEATURES_IN).

Map 12—Earthquake Epicenters 1804–2014
Data for this map were obtained from two sources: (1) earth-

quakes before 1973 (Stover et al. 1984) and (2) the USGS's NEIC catalog of earthquakes from 1973 to 2014 (USGS 1973–2014, http://earthquake.usgs.gov/earthquakes/eqarchives/epic/epic_rect.php, data retrieved July 2009). These data sets were combined into a single shapefile and overlaid onto a base map.

Acknowledgments

We acknowledge the contributions of our colleagues in Indiana, Kentucky, and Missouri, in particular Mary Parke, formerly Indiana Geological Survey; David Harris, Kentucky Geological Survey; and Thomas Thompson, Missouri Geology and Land Survey. This work was partially funded by National Science Foundation Grant EAR 09-52257 to the University of Illinois at Urbana-Champaign. Jennifer Carrell provided digital cartography.

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