

ArcGIS Maps Depicting Topography of the Basement-Cover Contact (the Great Unconformity), and the Traces of Faults and Folds, in the Cratonic Platform of the United States*

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Abstract

In the cratonic platform of the United States, the crust consists of Precambrian igneous and metamorphic rock ("basement") overlain by a relatively thin veneer of Phanerozoic sedimentary strata ("cover"). Regions underlain by cratonic-platform crust include the Midcontinent (the Interior Plains, the Appalachian Plateau, and the Ozark Plateau), the Rocky Mountains, and the Colorado Plateau. In the Midcontinent, land-surface topography does not provide insight into the location and character of tectonic structures, because sedimentary basins of the region have filled—surface relief primarily reflects the consequences of fluvial dissection of flat-lying strata, or landforms resulting from Quaternary and Holocene deposition. Tectonic structures are, however, delineated by variations in the elevation of the basement-cover contact (the "Great Unconformity"). We have produced a new ArcGIS digital "basement-topography map" representing regional-scale elevation variations of the Great Unconformity, both above and below ground, across the cratonic platform in the United States. This map, which can be presented either with or without shaded relief, covers the region between the Appalachian Mountains on the east, and the Basin and Range on the west. It reveals the 3-D shape of the Great Unconformity surface as it would appear if Phanerozoic strata were removed, and assists in visualization of epeirogenic domes, basins, and arches, as well as of major basement-penetrating faults. Since this contact lies at depth in much of the region studied, the map effectively provides an impression of variations in depth to basement, much as a structure-contour map would. Because the map is digital, it can be easily combined with other maps to provide a basis for interpreting regional geophysical and geological data. To help delineate the relationship between geologic structures and features on our basement topography maps, we also compiled a map showing the traces of Midcontinent folds and faults in the cratonic platform.

Introduction

The North American craton is a region of continental crust that has not undergone dynamothermal metamorphism and has not developed penetrative tectonic fabrics (foliations or cleavages) during the past 1 billion years (e.g., Sloss, 1988a; Hoffman, 1988; Whitmeyer and Karlstrom, 2007). Thus, it is tectonically "stable" relative to the Phanerozoic orogens (the North American Cordillera and the Appalachians) that formed along its margins. The craton includes the Canadian Shield, where Precambrian rocks are exposed at the surface, and the cratonic platform, where Precambrian rocks

lie buried beneath Phanerozoic sedimentary strata (e.g., Sloss, 1988a; 1988b). In discussing the craton, geologists refer to the Precambrian rocks, which are mostly igneous and metamorphic, as "basement," and refer to Phanerozoic sedimentary strata as "cover." Thus, the shield can be thought of as a region of exposed basement, and the platform as a region where a veneer of cover overlies the basement.

Cratonic-platform crust extends from the Wasatch Front (the eastern edge of the Basin and Range Rift) on the west, to the Appalachian Front (the western edge of the Appalachian fold-thrust belt) on the east, and from the Ouachita Front and Gulf Coastal Plain on the south, to the southern edge of the Canadian Shield on the north. Between the Wasatch Front and the Rocky Mountain Front, the cratonic platform has been uplifted and deformed by Mesozoic and Cenozoic faulting and folding—this region now comprises the Rocky Mountains and Colorado Plateau. East of the Rocky Mountains, the cratonic platform includes both a broad region of low relief known geographically as the Interior Plains, and two Interior Plateaus (the Appalachian and Ozark Plateaus). The Interior Plateaus are fluvially dissected regions where the land surface rises to elevations of 650 m. To simplify our discussion, we shall refer to the Interior plains and the Interior Plateaus together as the —Midcontinent.”

Though the Midcontinent is relatively stable, tectonically, as compared to Phanerozoic orogens of North America, it has not been completely stable. Specifically, during the Paleozoic, regional-scale epeirogenic basins, domes, and arches developed in the Midcontinent (e.g., King, 1955; Sloss, 1988a; Bunker et al., 1988; Bally, 1989; Bond and Kominz, 1991; Howell and van der Pluijm, 1999; Flowers et al., 2012), as did localized faults and associated monoclinial folds (e.g., Marshak and Paulsen, 1997; McBride and Nelson, 1999; Marshak et al., 2000; Marshak et al., 2003). This deformation did not, however, cause significant penetrative deformation, for strata of the region display only slight (<5%) intragranular strain, as manifested by twinning in calcite (Craddock and van der Pluijm, 1989; van der Pluijm et al., 1997). Mesozoic and Cenozoic-age development of significant structural relief (i.e., uplifts greater than 1 km) developed only in the part of the cratonic platform west of the Rocky Mountain Front, where it led to development of the Rocky Mountains and associated basins, as well as to the uplift of the Colorado Plateau (e.g., Burchfiel et al., 1992). Significant Mesozoic-Cenozoic structural relief has not developed in the Midcontinent, even though the region remains seismically active and earthquake epicenter maps delineate distinct seismic zones (e.g., New Madrid, Wabash Valley, and East Tennessee; Stein et al., 2009).

To highlight tectonic features of the cratonic platform of the United States—especially in the Midcontinent, we have produced ArcGIS digital maps depicting variations in the elevation of the basement-cover contact, relative to sea level (Domrois et al., 2012; Domrois, 2013). Since the contact lies below sea level, through most of the map area, most contours have negative values. We provide this map in three versions: in the first, contour lines represent elevations ([Figure 1](#)); in the second, variations in color represent variations in elevation ([Figure 2A, B](#)), and in the third, elevation variations have been highlighted by addition of shaded relief ([Figure 3](#)). In effect, these maps provide a 3-D representation of the shape of the continent-wide Great Unconformity, a surface representing the interval of erosion that occurred during the Late Precambrian, prior to the deposition of Paleozoic strata (Peters and Gaines, 2012; Karlstrom and Timmons, 2012). Because basement generally lies beneath tens to thousands of meters of cover strata, the surface portrayed on our map effectively serves as a subsurface structure-contour map that illustrates regional variations in the depth to basement.

Below, after explaining how we constructed the maps, we present the maps and highlight first-order features of basement topography. To emphasize structural features that control basement topography, we also provide a preliminary map showing the traces of Midcontinent faults and folds.

Map Production

Previous Work

Numerous maps produced during the past half century have used structure contours and/or color variations to portray basement topography and, therefore, to give an impression of variations in the depth to basement. Most of the data used to constrain contours on these maps came from well logs, but more recent maps also utilize constraints based on the interpretation of seismic-reflection profiles. Faults shown on these maps are based on recognition of offset markers, and in some cases, of gravity or magnetic anomalies.

Continent-scale maps illustrating regional basement topography include the 1:5,000,000-scale *Basement Map of North America* (AAPG-USGS, 1967) and the 1:2,500,000-scale *Basement Rock Map of the United States* (Bayley and Muehlberger, 1968). Both maps provide a generalized interpretation of basement topography and depict major faults in the cratonic platform. The *Tectonic Map of North America* (King, 1969) provides a simplified contour map of basement topography and emphasizes major basins by using color shadings keyed to the thickness of Phanerozoic strata. The *Tectonic Map of North America* produced by Muehlberger (1992) also portrays basement topography using color variations. Maps portraying parts of a state, a whole state, or several adjacent states, have been prepared for portions of the cratonic platform, and these reveal the local form of the Precambrian top surface in greater detail. However, each local map tends to have a unique scale and contour interval, and cannot be easily correlated with neighboring maps; therefore, contours and faults depicted on detailed maps commonly end abruptly at the boundaries between adjacent maps.

Entering Basement-Topography Data into ArcGIS

Our new basement-topography maps were developed using ArcGIS (©ESRI, Environmental Systems Research Institute), a commercial software product designed to compile and display geo-referenced spatial data sets. In ArcGIS, each top-of-basement data point can be represented by three numbers: elevation relative to sea level, latitude, and longitude. Most data sources we used provided elevation in feet, so we entered the data in feet, but output can be provided in English or metric units. To switch to meters, we multiplied feet by 0.3048. In cases where elevation values were provided relative to the ground surface, we adjusted them so that they represent elevation relative to mean sea level.

The following sources provided useable data ([Table 1](#) provides references): (1) *Existing digital data, in ArcGIS, depicting contour lines on the basement surface*: These data come in the form of geodatabase files, dxf files, and shapefiles. A "shapefile" is a digital vector diagram representing a shape. Examples include contour lines, fault or fold traces, and unit contacts. Such data are available for a few states, or portions of states; (2) *Scanned images of existing structure-contour maps on the surface of basement*: Some of these data are in the form of paper maps, and some in the form of downloadable raster (dot matrix) images. To obtain enterable data from printed maps, we first scanned an image of the source map to yield a digital image. Then, after adjusting the image in ArcMap so as to fit the projection of our base map, we hand-traced contour lines on the screen by using a digitizing tool in ArcMap, a process that generated shapefiles representing the contour lines. Values of elevation relative to sea level for each contour line were recorded in an attached attribute table; (3) *Point data from catalogs of well data*: Well logs for basement-penetrating wells provide point data on depth to basement. We used well data where available, and only where the value for depth to basement could be confidently adjusted relative to mean sea level so that depths provided could be specified accurately. Point data were entered into an Excel spreadsheet which was then imported into ArcMap; (4) *Point data obtained by measuring elevation of basement, as depicted on published cross sections*: For some locations,

neither basement-contour maps nor drill-hole data are available. In some cases, previous authors have published scaled cross sections (some of which are based on seismic-reflection profiles) representing subsurface structure. We were able to obtain basement-elevation data along the length of a cross section by first pasting a scan of the cross section into Adobe Illustrator™. In Illustrator, we created a vertical scale that could be moved along the cross section so that depths below sea level could easily be measured at regular intervals. We also used this method to mark the locations of basement-penetrating faults that intersected the line of section. Depth data were translated into elevation data, and then the latitude, longitude, and elevation information for each point that we measured on a cross section was entered into an Excel spreadsheet, which was then imported into ArcMap as if it were drill-hole point data.

For localities where the Great Unconformity has been eroded so that exposed bedrock at the ground surface consists of Precambrian rock, we imported ground-surface elevation information that we obtained from the 30 arc-second digital elevation map (DEM) of North America into our data base. On our basement-topography map, places where bedrock at the ground surface consists of Precambrian units were colored red, in order to stand out.

Unfortunately, our digitizing procedures introduce some error into the map compilation. Part of this error comes from scanning (for scanning lenses do not reproduce images exactly), part comes from stretching and distorting within ArcMap to fit the source map to the base map (for the process does not produce a perfect match across the entire area of the map, especially if the source map was not the same projection as the base map), and part comes from the process of tracing contour lines (since the inherent inaccuracy of hand motions means that the tracing is not exact). Also, contour maps, by their nature, are not unique solutions to point data. We estimate that tracings on the base map have a map-plane position error up to 500 m. Due to errors made during geo-referencing, or errors on the source maps themselves, contours did not all line up across state boundaries. We adjusted non-matching and crossing contours by hand, so that the contours appear as smooth lines with no boundaries at state borders. If enough information was present for major faults, the contours were adjusted to stop at or near the fault traces.

Production of Basement-Topography Maps

Once we entered all data on the elevation of basement elevation into ArcMap, we used the built-in features of ArcGIS to produce a basement-topography map. In effect, ArcGIS rationalizes all inputs concerning depth to basement, regardless of source, to yield a single data set that can be then employed to produce a single set of contour lines ([Figure 1](#)). Using the same data, we used the "Topo-to-Raster" tool in ArcGIS to transform point and line shapefiles into a raster image on which variations in color represent variations in basement elevation ([Figure 2A, B](#)). This map employed a stretched color scheme. We made two versions, one encompassing a palette that extends from light yellow to dark brown, and one encompassing a palette that extends from white to dark gray. On both versions of this map, lighter colors represent higher areas, such as occur at the crests of domes and arches, and darker colors represent deeper areas such as occur on the floors of basins. These maps resemble the maps produced by King (1969) and Muehlberger (1992).

To make visualization of basement topography more intuitive, we also produced a shaded-relief map of depth to basement ([Figure 3](#)). The shading, which simulates shadows that would be produced by the low-angle sun of late afternoon, was created by applying the "Hillshade" tool in ArcGIS to the completed Topo-to-Raster image. The Hillshade image was made 50% transparent and then was placed over the Topo-to-Raster color image. To create a 3-D look, the Topo-to-Raster and Hillshade images can be added to either an ArcScene or an ArcGlobe document. In the Midcontinent,

vertical distances portrayed on the map are so much shorter than the horizontal distances that we multiplied depths to produce a vertical exaggeration of 10X, to make basement-topographic features stand out.

Our depth-to-basement data only covers the cratonic platform. Since we did not enter data for orogens, or for the Atlantic and Gulf coastal plains, these regions appear as featureless areas on our map, an image that can be confusing. Thus, to provide a geologically meaningful edge to the data-constrained portion of our map, we added a shapefile (labeled `_Cordillera'`) to define the foreland edge of the region of the North American Cordillera that lies to the west of cratonic-platform crust, a shapefile (labeled 'Appalachians') to delineate the thrust front of the Appalachian orogen, and a shapefile (labeled `_Coastal Plain'`) to delineate the northern edge of regions that were submerged when sea level was high during the Cretaceous and Early Cenozoic.

In general, we masked the area west of the Cordillera shape file, the area south or east of the Coastal-Plain shape file, and the area east of the Appalachian shapefile. But there are two exceptions to this rule. First, we removed the mask covering the Mississippi Embayment, a region where coastal-plain sediments extend northward, up the Mississippi Valley due to subsidence of the southern Mississippi Valley (e.g., Cox and Van Arsdale, 2002). By depicting basement topography beneath the Mississippi Embayment, our map illustrates the position of the Reelfoot Rift. Second, we removed the mask covering the portion of the Appalachians between the foreland edge of the Appalachian fold-thrust belt and the exposed Grenville basement thrust slices exposed along the axis of the Appalachians. We included this region because it encompasses the deeper portion of the Appalachian Basin as well as underlying rift basins, such as the Birmingham Graben. Addition of this data provides an image of the structural architecture of the cratonic platform along its eastern and southern margins, even in regions where it is covered by younger strata.

Production of a Fault-and-Fold Map

To help interpret the basement-topography map, we also prepared a map delineating the location of documented structural features (namely, Midcontinent fault-and-fold zones; Marshak and Paulsen, 1997) that may cut or warp the Great Unconformity, or may splay from faults that cut the Great Unconformity ([Figure 4](#)). The data used for the production of this map was obtained from an extensive literature search, which proved to be a challenge because much of the data resides in state geological survey reports that are somewhat difficult to locate (see [Table 2](#) for references). Relatively few of these structures are well exposed at the ground surface; consequently, their presence is based on studies that use well-correlation to define offsets of subsurface stratigraphic marker horizons or, in a few cases, by seismic-reflection profiles. Shapefiles were created for each structure, after the source map for the structure was adapted to the scale and projection of the same map base that we used for compiling basement topography data. Additional details about the structures were entered into an attribute table that adjoins the shapefile.

Observations: Basic Structural Domains

Our new shaded-relief map of basement-topography provides an improved visual image of tectonic features in the cratonic platform of the United States ([Figure 3](#)). It makes the location and orientation of tectonic features (basins, uplifts, and faults) stand out. Based on the distribution and character of these features, our map emphasizes that the cratonic-platform crust consists of four distinct domains, described below ([Figure 5](#)).

The Midcontinent Domain

This region of relatively low structural relief and gentle surface-slope gradients extends from the Rocky Mountain Front on the west to the Appalachian Front on the east. The southern limit is delineated by a belt of deep troughs that we refer to as the "Bordering Basins" domain (discussed below), and its northern limit is the edge of the Canadian Shield. In specific locations, the basement surface of the Midcontinent domain has been displaced by faulting. Faults appear as distinct steps in the basement topography. Examples include the borders of the Proterozoic-age (1.1 Ga) Midcontinent Rift, which can be traced, on the map, from Minnesota to Kansas, and the Nemaha Ridge, which cuts across Kansas and southeastern Nebraska (e.g., Stein et al., 2014). Of note, the Midcontinent Rift appears as a positive feature on our shaded-relief map, even though this feature originated as an extension-related rift trough—this fact emphasizes that the border faults that initiated as normal faults during rifting were inverted to become reverse faults.

The Bordering Basins Domain

Several deep, elongate basins outline the southern and eastern edges of the Midcontinent Domain. These "bordering basins" have long been recognized, both from drilling and seismic reflection data—our new shaded-relief map of basement topography simply emphasizes their distribution and shape. From west to east, the bordering basins include: the Permian basin of the Texas/New Mexico border, the Anadarko basin of Oklahoma, the Arkoma basin of Oklahoma and Arkansas, the Reelfoot Rift of eastern Arkansas and southeastern Missouri, the Rough Creek Graben of western Kentucky, and the Rome Trough of eastern Kentucky through Pennsylvania. Along the foreland edge of the Appalachians, a second chain of basins lies to the east of the bordering basins we have just mentioned. This second set, which has been partially overthrust by the foreland edge of the Appalachian fold-thrust belt, includes the Birmingham Graben of northern Alabama (Thomas and Bayona, 2005), and a series of troughs on the interior edge of the Appalachian basin.

The Rocky Mountains Domain

This domain includes the portion of the Rocky Mountains in which basement-cored uplifts developed during the Laramide Orogeny (~ 80 to 40 Ma). This region is underlain by cratonic platform crust, in that the crust consists of Precambrian basement overlain by relatively thin Phanerozoic cover. The region did not undergo the lithospheric thinning and subsequent subsidence, as happened in the Cordillera west of the Wasatch Front. Our basement-topography map emphasizes important differences between the Rocky Mountain domain and the adjacent Midcontinent domain. First, structural relief (the difference between the elevation of the Great Unconformity exposed on basement uplifts and the subsurface elevation of this contact in adjacent basins) is on the order of 10 to 12 km in the Rocky Mountains domain, but is generally less than 4 km in the Midcontinent domain. Second, structural relief in the Rocky Mountain Domain reflects present-day topography in that Laramide basement uplifts are also significant topographic uplifts, but it does not in the Midcontinent domain. Third, the spacing between basement highs in the Rocky Mountain domain is a factor of two to four less than it is in the Midcontinent domain—for example, the distance between the uplift axes in the Midcontinent is about 400 km, whereas the distance between uplift axes in the Rocky Mountain domain is between 50 and 200 km. Of note, the Rocky Mountain front, which represents the boundary between the Rocky Mountain domain and the Midcontinent is an abrupt feature, in that there is not gradational transition between the relief and spacing of structures found in the former and that found in the latter.

The Colorado Plateau Domain

The Colorado Plateau Domain, which covers portions of Arizona, Utah, New Mexico, and Colorado, also consists of cratonic platform crust, as demonstrated dramatically by exposures in the Grand Canyon, where Colorado River erosion has exposed the Great Unconformity. This region differs from the Midcontinent domain in a few ways. First, the average elevation of the Great Unconformity is higher beneath the Colorado Plateau than beneath the Midcontinent. Second, the current level of the land surface intersects several faults, and intersects monoclines just above the tip line of faults. Therefore, tectonic structures in the Colorado Plateau Domain control the shape of many contemporary landforms in the Colorado Plateau, while they generally do not in the Midcontinent domain. For example, the East Kaibab Monocline within the Colorado Plateau Domain forms a distinct step in the land surface and defines the edge of the topographic Kaibab Plateau (e.g., Huntoon 1993). In contrast, the Du Quoin Monocline, of southern Illinois, does not affect the landscape at all (Johnson, 1998). Finally, while structural relief in the Colorado Plateau Domain is less than that of the Rocky Mountains Province, it is larger than that in the Midcontinent Domain.

Conclusions

A new basement-topography map of cratonic-platform crust in the United States provides a means to visualize the location, shape, and trend of tectonic features (basins, domes, arches, and fault-and-fold zones), many of which are buried and not manifested by ground-surface topography. This map, either in the form of a contour map, a colored contour map, or a shaded relief map, represents present-day regional elevation variations of the Great Unconformity (both above and below sea level). It emphasizes that cratonic platform can be subdivided into several domains based on the amplitude and spacing of structures, and on structural relief. A digital map representing the traces of faults and folds as shapefiles, when overlain on the shaded-relief map, provides insight into possible structural controls on variations in the basement of the cratonic platform ([Figure 6](#)).

Because of the sparseness of data delineating depth to basement across much of the region covered by our map, the map lacks detail in many locations. But in its present form, it can serve as a base map for plotting other types of geological or geophysical data, and thus can provide a context for interpretation. Also, because the map data exists in ArcGIS format, it can be modified and upgraded easily. As new data become available, and the maps are refined, they will provide additional new insight into the tectonics of North America's cratonic platform.

Structure contour map of the Cratonic Platform, USA

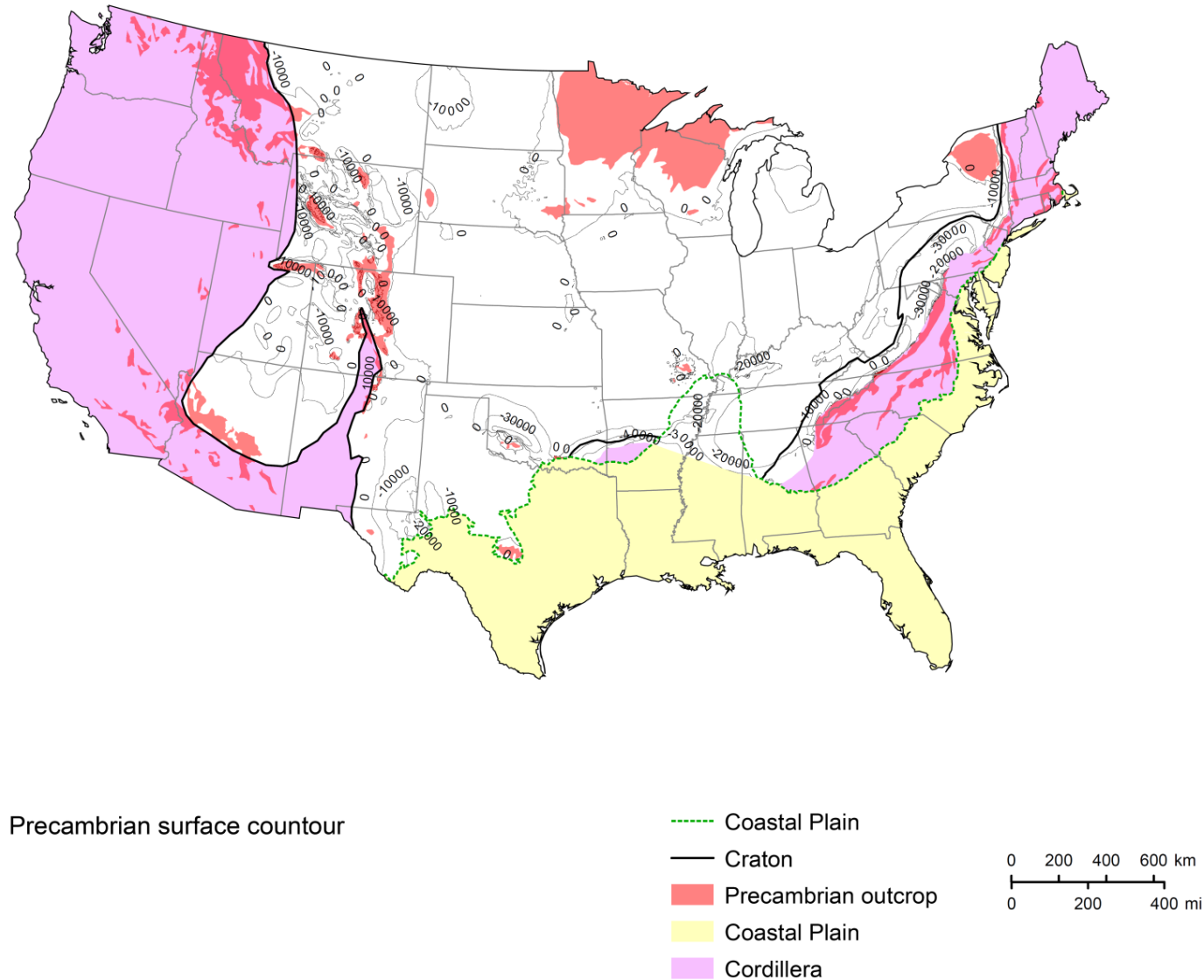


Figure 1. Basement topography of the cratonic platform in the United States, as represented by structure contour lines on the Great Unconformity, meaning the contact between Precambrian "basement" and Phanerozoic sedimentary "cover" (the Great Unconformity). Values for the contour lines are elevation above or below sea level. Contour interval = 10,000 feet. Note that the data base underlying this map can allow production of a contour map at any desired contour interval. [Table 1](#) provides the sources of data used in production of this map.

Structure contour map of the Cratonic Platform, USA

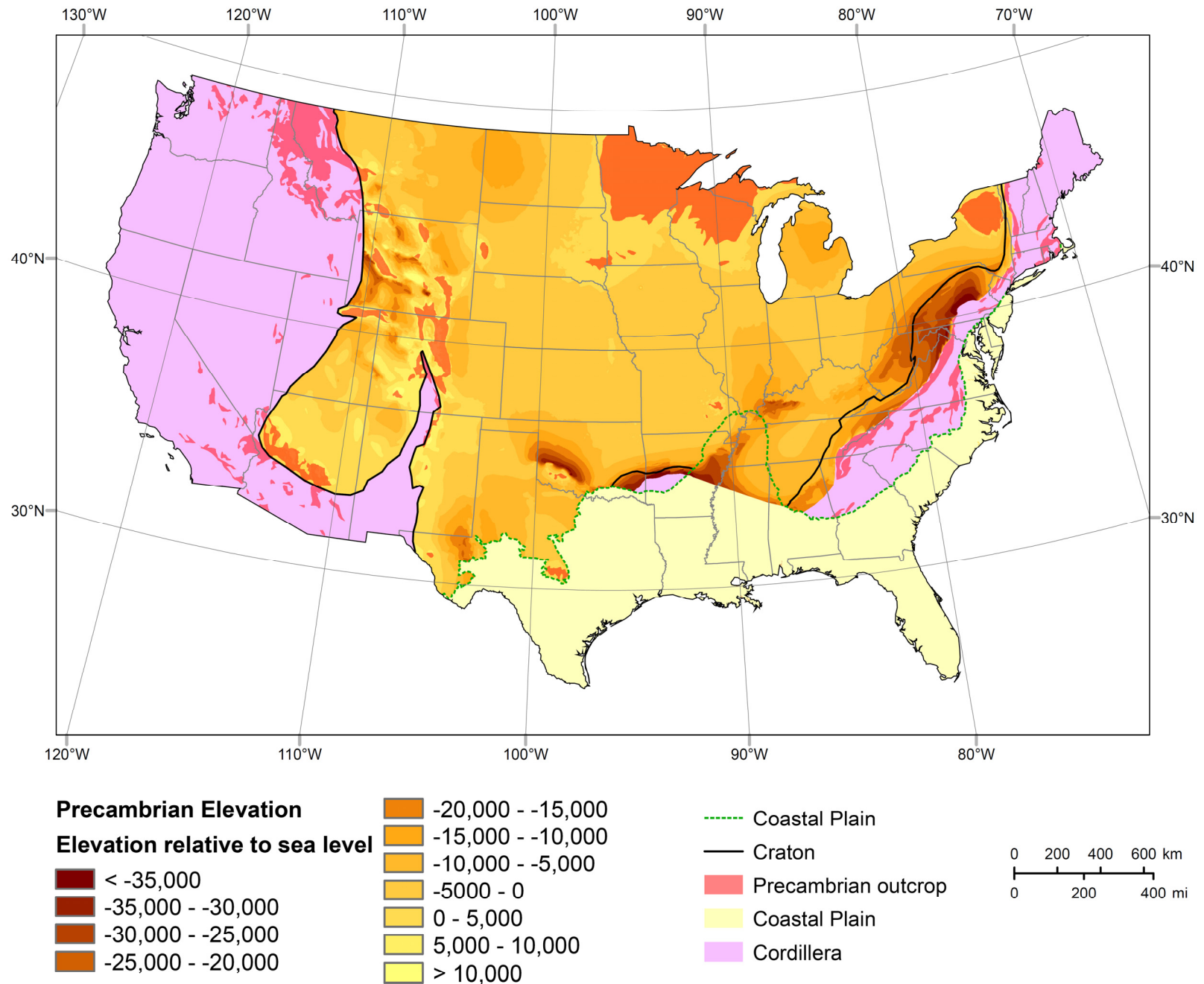


Figure 2A. Colored basement-topography map, using a yellow to brown palette. Each color area represents the specified range of topography.

Structure contour map of the Cratonic Platform, USA

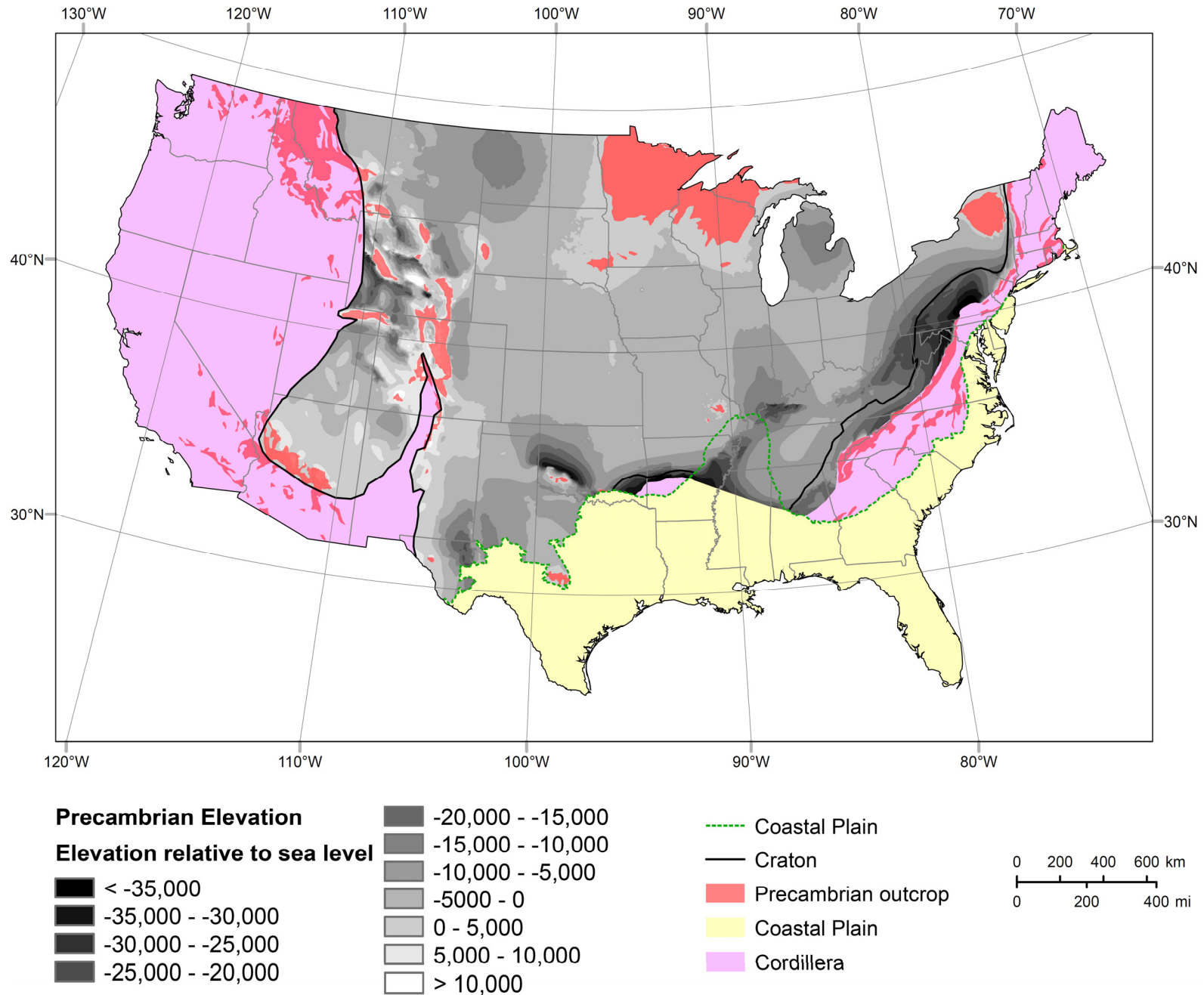


Figure 2B. Colored basement-topography map, using a white to gray palette. Each color area represents the specified range of topography.

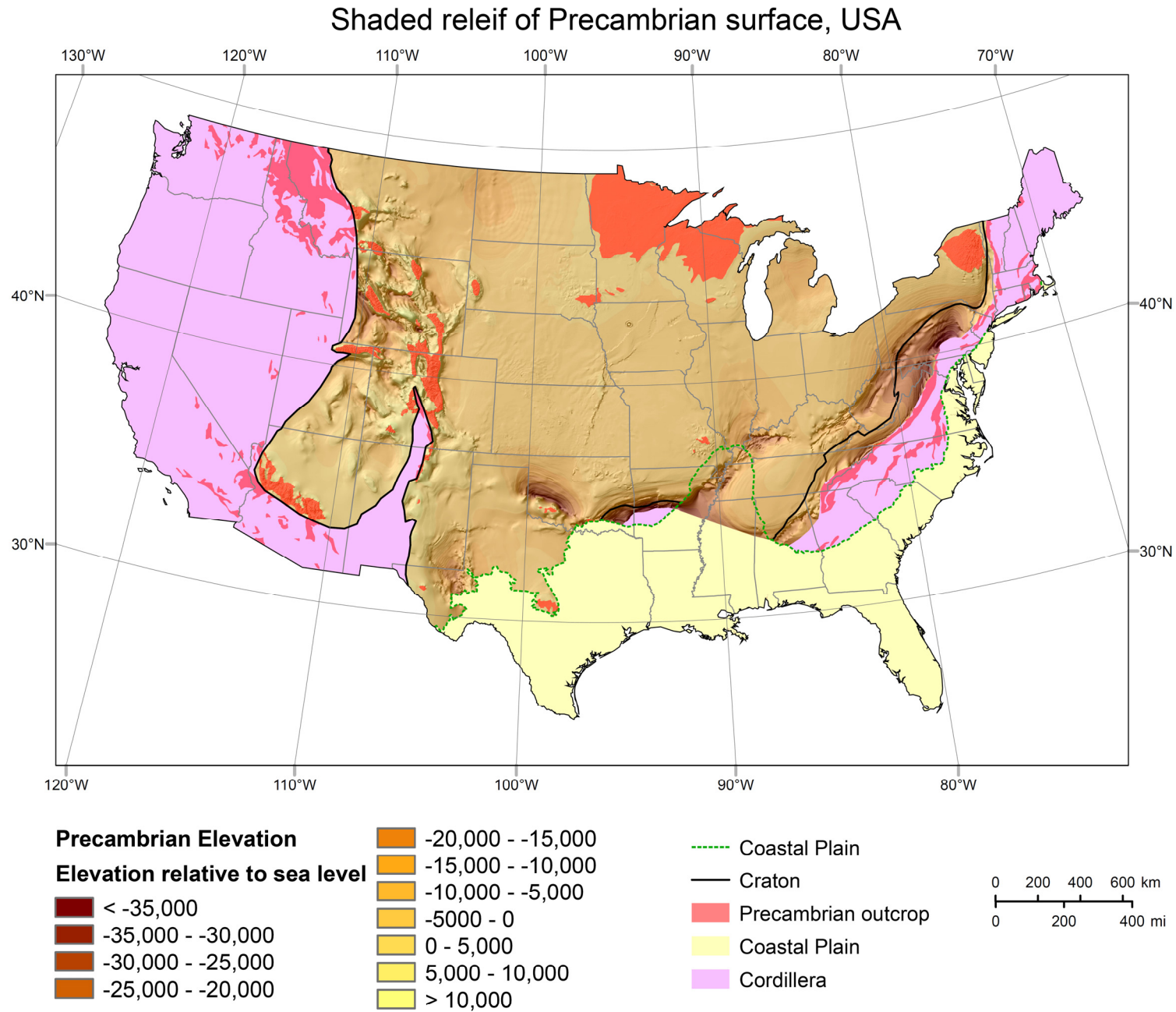


Figure 3. Shaded-relief version of the basement-topography map, which effectively displays the depth to the Great Unconformity. Darker colors occur where the Great Unconformity is deeper, and thus represent sedimentary basins. Places where basement is exposed at the ground surface are colored in red. The light yellow area is the coastal plain, and the purple areas are Phanerozoic orogens.

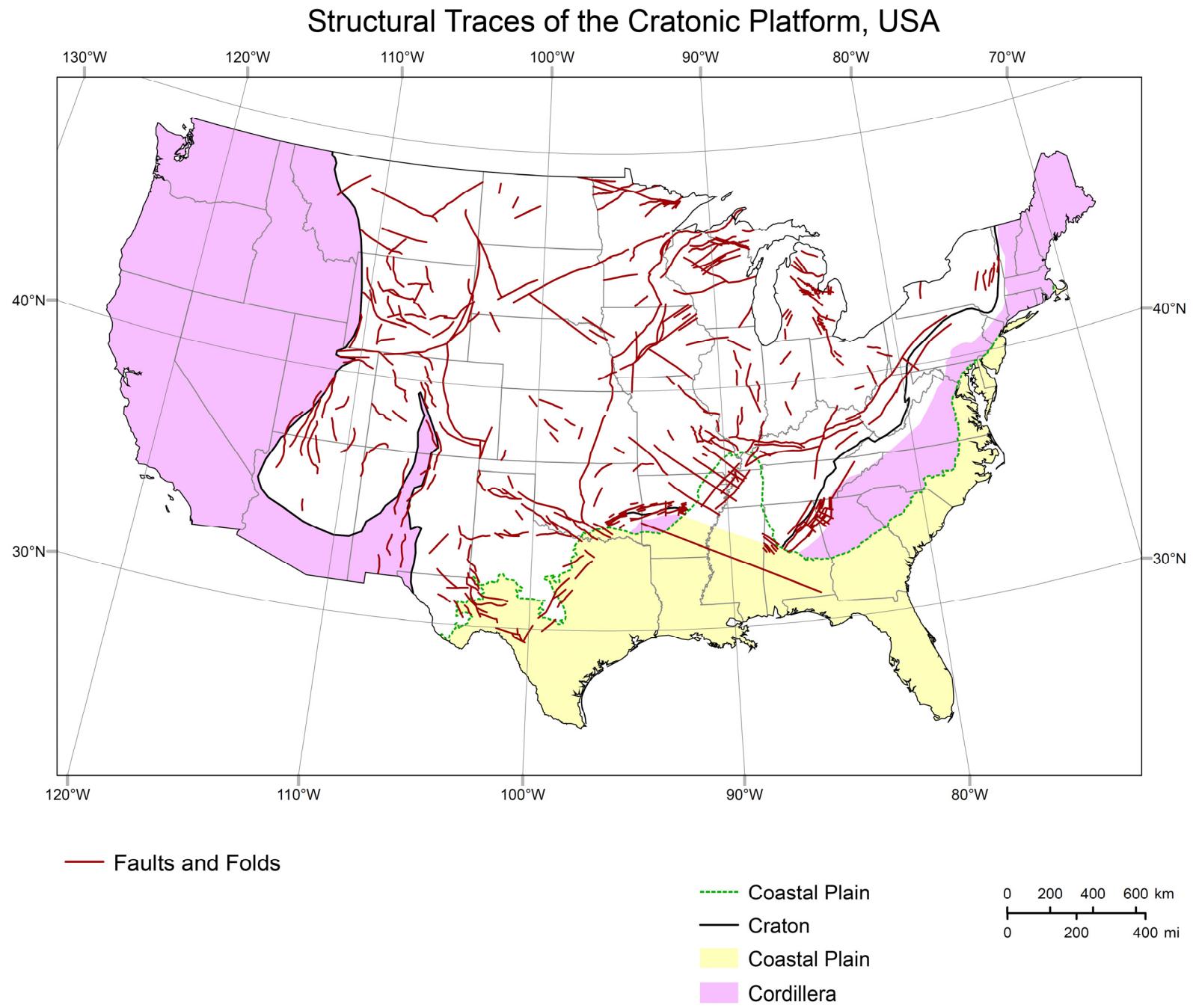


Figure 4. Traces of principal geologic structures in the cratonic platform region of the United States. Each red line represents a documented fault or fold trace. [Table 2](#) provides data sources for these traces. Further details are provided by Domrois (2013).

Principal structural domains of the Cratonic Platform, USA

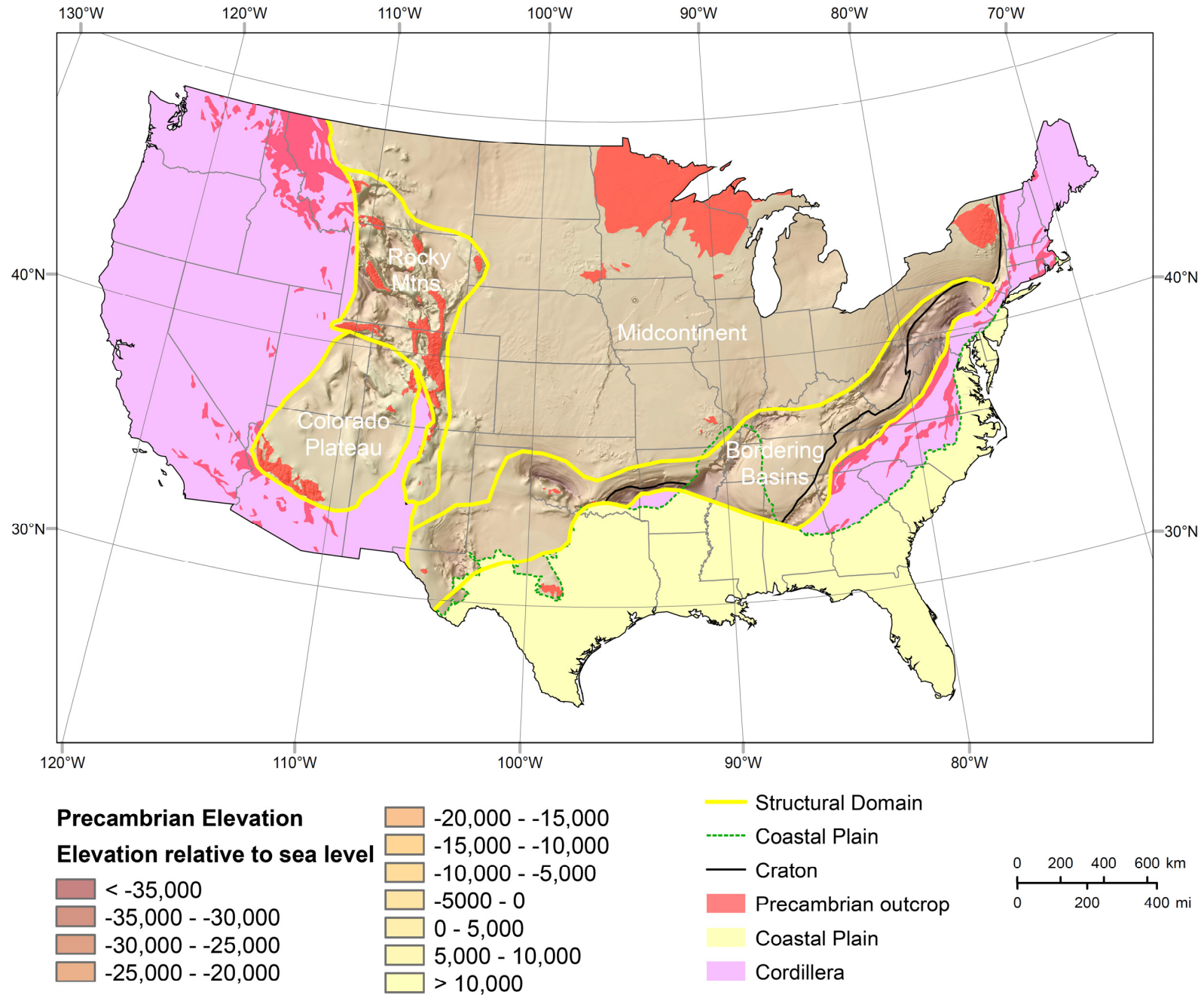


Figure 5. Regional structural-style domains of the cratonic platform. See the text for descriptions.

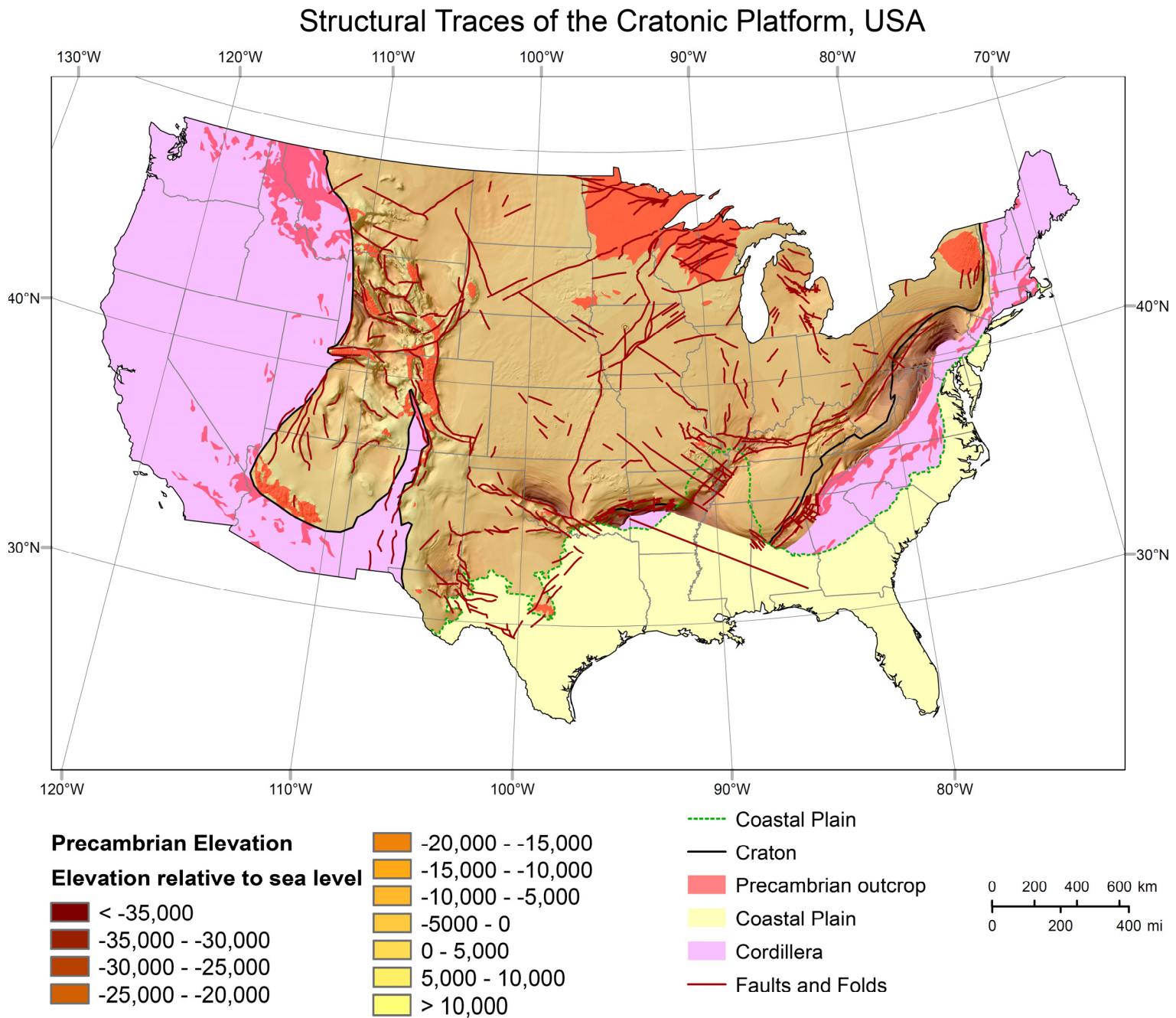


Figure 6. An overlay of the structure shapefiles on the shaded-relief map of basement topography, illustrating the relationship between structures and variations in depth to basement.

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<i>Region</i>	<i>Source</i>
Alabama	Groshong et al. (2010)
Appalachian basin	Thomas (1988)
	Kulander and Dean (1986)
	Patchen et al (2006)
	Schumaker and Wilson (1996)
	Thomas and Bayona (2005)
Colorado	Hemborg (1996)
Illinois	Buschback and Kolata (1990)
	Collinson et al (1988)
	Kolata and Nelson (1997)
Iowa and surrounding areas	Anderson (1995; 2006)
Kansas	Cole (1976)
	Merriam (1963)
Kentucky	Drahovzal and Noger (1995)
	Solis et al. (2005)
Ohio	Baranoski (2002)
Oklahoma	Campbell and Webber (2006)
	Perry (1989)
	Robbins and Keller (1992)
Missouri	Kisvarsanyi (1984)
Michigan	Milstein (1988)
Minnesota	Sims (1990)
Montana	Bergantino and Clark (1985)
Nebraska	Carlson (1970)
	Burchette and Carlson (1986)
New York	Rickard (1973)
Pennsylvania	Saylor (1999)
Permian Basin (Texas; New Mexico)	Adams and Keller (1995)
	Ruppel et al. (2005)
Rocky Mountain Region	Woodward (1984)
South Dakota	McCormick (2010a; b)
Texas	Ewing (1990)
United States (entire)	Bayley and Muehlberger (1968)
	AAPG-USGS (1967)
	King (1969)
	King and Edmonston (1972)
	Muelberger (1992)
	Sims et al. (2008)
Wyoming	Blackstone (1993)

Table1. Representative sources for the basement-topography map.

TABLE 2. Representative Sources for the Basement Fault-and-Fold Map

<i>Region</i>	<i>Source</i>
Oklahoma	Arbenz (2008) Burchett et al. (1985) Cox and Van Arsdale (1988) Crone and Luza (1986) Luza et al. (1987) Perry (1989) Ramelli and Slemmons (1986)
Kansas	Baars and Watney (1991)
United States	Bayley and Muelberger (1968) AAPG-USGS(1967) King (1969) Muelberger (1992)
Appalachian foreland	Bayona et al. (2003) Bayona and Thomas (2003) Gao et al. (2000) Groshong et al. (2010) Hatcher et al. (1989) Hatcher et al. (2007) Hickman (2011) Kulander and Dean (1986) McDowell (1986) Powell et al. (1994) Root and Onasch (1999) Stark (1997) Thomas (1976; 2010; 2011) Thomas and Bayona (2005)
Illinois	Bear et al. (1997) Duchek et al. (2004) Harrison and Schultz (2002) Kolata and Nelson (1997) McBride and Nelson (1999) Nelson (1995a) Nelson (2010)
Kansas	Berendsen (1997) Brown et al. (1983)
Wyoming	Blackstone (1993)
Ohio	Brannock (1993) Onasch and Kahle (1991)
Michigan	Braschayko (2005) Esch (2010)
Iowa	Bunker et al. (1985)
Nebraska	Burchett and Carlson (1986)

<i>Region</i>	<i>Source</i>
Midcontinent	Cannon (1994) Cannon et al. (1991) Carlson (1997) Cox (2010) Crone and Wheeler (2000) Csontos et al. (2008) Hickman (2011) Karlstrom and Humphreys (1998) Magnani et al. (2004) Marshak and Paulsen (1997) Marshak et al. (2003) Nichols et al. (1989) Sims (1972; 1990; 1992) Sims and Morey (1972) Sims et al. (1991; 2008) Van Schmus (1992) Van Schmus et al. (1989) Wicks et al. (1999) Woodward (1984) van der Pluijm and Catacosinos (1996)
Rocky Mountains / Colorado Plateau	Davis (1999) Paylor and Yin (1993) Stone (1993) Timmons et al. (2001)
Missouri	Clendenin et al. (1989) Steeple (1982) McCracken (1966)
Kentucky	Drahovzal and Noger (1995) Solis et al. (2005)
Texas	Ewing (1990)
New York	Fakundiny and Pomeroy (2002) Jacobi (2002)
North Dakota	Heck (1988)
Minnesota	Gibbs et al. (1984) Jirsa et al. (2011)
Colorado	Hemborg (1996) Kluth and Schaftenaar (1994)
Missouri	McCracken (1966)
Kansas	Merriam (1963)
Montana	Nelson (1995) Woodward et al. (1997)

Table 2. Representative sources for the basement-fault-and-fold map.