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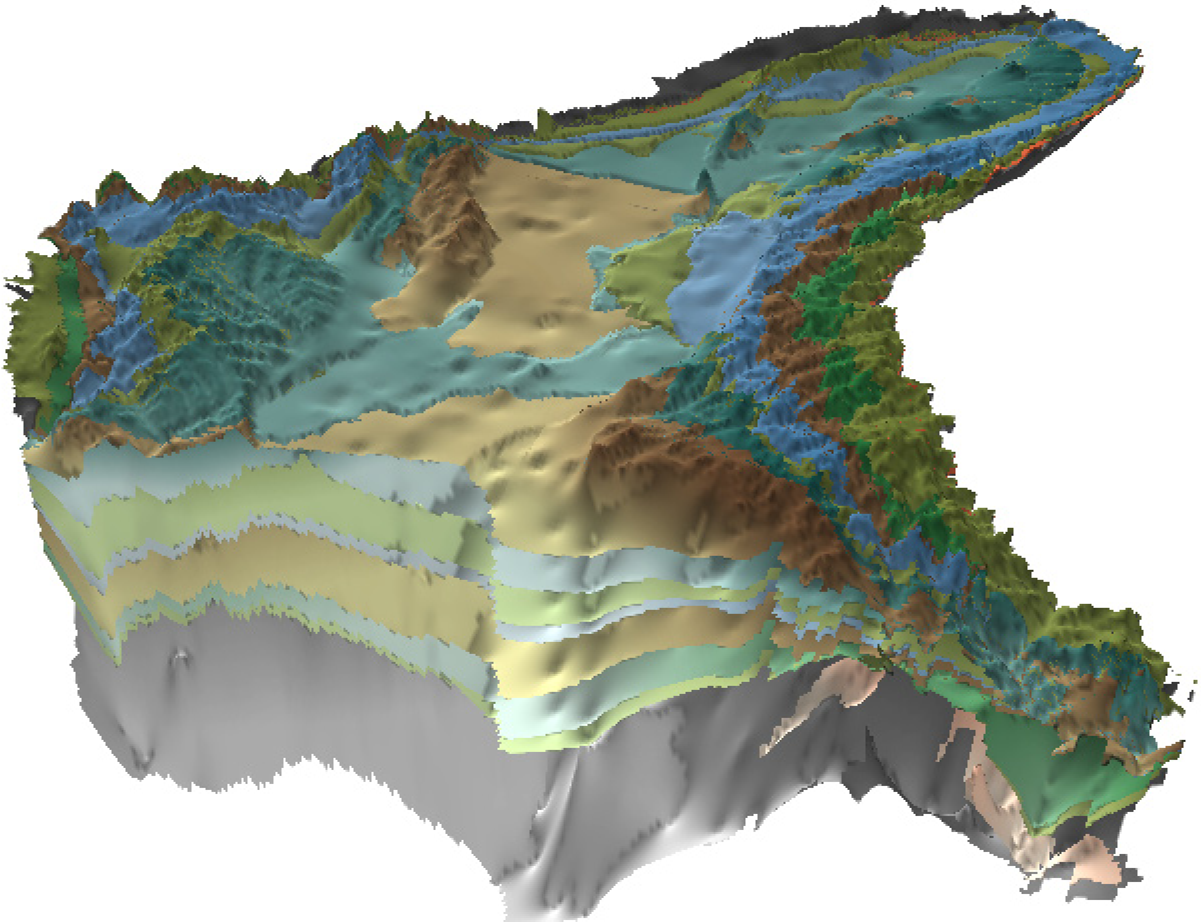
Digital Surfaces and Thicknesses of Selected Hydrogeologic Units within the Mississippi Embayment Regional Aquifer Study (MERAS)



Scientific Investigations Report 2008–5098

U.S. Department of the Interior
U.S. Geological Survey

Front cover. Hydrogeologic unit surfaces from the report displayed in a 3-dimensional view with 50 times the vertical exaggeration.

Digital Surfaces and Thicknesses of Selected Hydrogeologic Units within the Mississippi Embayment Regional Aquifer Study (MERAS)

By Rheannon M. Hart, Brian R. Clark, and Susan E. Bolyard

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U.S. Department of the Interior
U.S. Geological Survey

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Conversion Factors

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)

Vertical coordinate information is referenced to the North American Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above or below the vertical datum.

Digital Surfaces and Thicknesses of Selected Hydrogeologic Units within the Mississippi Embayment Regional Aquifer Study (MERAS)

By Rheannon M. Hart, Brian R. Clark, and Susan E. Bolyard

Abstract

Digital surfaces of selected Tertiary and younger age hydrogeologic units within the Mississippi embayment aquifer system were created using more than 2,600 geophysical logs for an area that covers approximately 70,000 square miles and encompasses parts of eight states. The digital surfaces were developed to define and display the hydrogeologic framework for the Mississippi Embayment Regional Aquifer Study (MERAS). The digital surfaces also provide a foundation of the selected hydrogeologic units for development of a steady-state and transient regional ground-water flow model of the Mississippi embayment aquifer system from the top of the Midway confining unit upwards to land surface. The ground-water flow model is under development as part of the U.S. Geological Survey Ground-Water Resources Program.

Using a Geographic Information System, nine digital surfaces of the tops of selected hydrogeologic units were created using the Australian National University Digital Elevation Model method as an interpolation scheme. Thickness maps also were constructed using the Geographic Information System by calculating the difference between the altitude of the interpreted base of an overlying unit and the altitude of the interpreted top of an underlying unit. In general, the highest hydrogeologic unit altitudes are located along the eastern edge of the study area in the outcrop, and the lowest altitudes, in general, are located along the southern edge of the study area along the axis of the embayment. The Mississippi River Valley alluvial aquifer and the lower Claiborne aquifer are the thinnest aquifers of importance in the study area; the thickest aquifer of importance is the middle Claiborne aquifer.

Introduction

The Mississippi Embayment Regional Aquifer Study (MERAS) is being conducted by the U.S. Geological Survey (USGS) Arkansas Water Science Center with assistance from the USGS Louisiana Water Science Center, USGS Mississippi Water Science Center, and USGS Tennessee Water Science Center. The MERAS began in 2006 as a 3-year effort to determine ground-water availability within the Mississippi embayment, an area that encompasses about 70,000 mi^2 and parts of eight states including Alabama, Arkansas, Illinois, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee.

As part of the MERAS, digital surfaces and thicknesses of the principle hydrogeologic units from the top of the Midway confining unit of upper Paleocene age to land surface are needed for the eight-state study area. The digital surface and thickness maps provide a GIS framework for defining and displaying the hydrogeologic surfaces within the MERAS. The digital surface and thickness maps are being used to construct a ground-water flow model being developed as part of the MERAS to aid in evaluating ground-water availability in the Mississippi embayment (U.S. Geological Survey, 2007).

Purpose and Scope

The purpose of this report is to provide digital maps of the surfaces and thicknesses of selected hydrogeologic units within the Mississippi embayment aquifer system that were derived from interpretation of geophysical logs at more than 2,600 locations within the Mississippi embayment. These units include the Mississippi River Valley alluvial aquifer, Vicksburg-Jackson confining unit (contained within the Jackson Group), the upper Claiborne aquifer (contained within the Claiborne Group), the middle Claiborne confining unit (contained within the Claiborne Group), the middle Claiborne aquifer (contained within the Claiborne Group), the lower Claiborne confining unit (contained within the Claiborne Group), the lower Claiborne aquifer (contained within the Claiborne Group), the middle Wilcox aquifer (contained within the Wilcox Group), the lower Wilcox aquifer (contained within the Wilcox Group), and the Midway confining unit (contained within the Midway Group) (table 1). The scope of this effort included interpretation of the top of each hydrogeologic unit of interest using normal-resistivity, natural-gamma, and spontaneous potential geophysical logs, which in most cases, were based on tops of geologic units described in table 1. Geophysical logs were chosen for inclusion in the

Table 1. Hydrogeologic and geologic units and their correlation across the States with the Mississippi Embayment Regional Aquifer Study.

<table>
<tr><th rowspan="2">ERATHEM</th><th rowspan="2">SYSTEM</th><th rowspan="2">EPOCH</th><th rowspan="2">GROUP</th><th rowspan="2">LOUISIANA</th><th colspan="2">ARKANSAS</th><th rowspan="2">MISSOURI</th><th rowspan="2">KENTUCKY</th><th rowspan="2">TENNESSEE</th><th rowspan="2">MISSISSIPPI</th><th rowspan="2">ALABAMA</th><th rowspan="2">Hydrogeologic units</th></tr>
<tr><th>Southern</th><th>Northeastern</th></tr>
<tr><td rowspan="13">CENOZOIC</td><td rowspan="2">QUATERNARY</td><td>HOLOCENE</td><td rowspan="2"></td><td colspan="4" rowspan="2">Alluvium and terrace deposits</td><td colspan="2" rowspan="2">Alluvium and loess deposits</td><td rowspan="2">Alluvium, terrace, and loess deposits</td><td rowspan="2">Alluvium and terrace deposits</td><td rowspan="2">Mississippi River Valley alluvial aquifer</td></tr>
<tr><td>PLEISTOCENE</td></tr>
<tr><td rowspan="11">TERTIARY</td><td>OLIGOCENE</td><td>Vicksburg</td><td>Vicksburg Formation</td><td colspan="5">Not present in study area</td><td colspan="2">Vicksburg Formation</td><td rowspan="2">Vicksburg-Jackson confining unit</td></tr>
<tr><td rowspan="6">EOCENE</td><td>Jackson</td><td colspan="8">Jackson Formation</td></tr>
<tr><td rowspan="5">Claiborne</td><td colspan="7">Cockfield Formation</td><td>Gosport Sand</td><td>Upper Claiborne aquifer</td></tr>
<tr><td colspan="8">Cook Mountain Formation</td><td>Middle Claiborne confining unit</td></tr>
<tr><td colspan="2">Sparta Sand</td><td colspan="2" rowspan="3">Memphis Sand</td><td>Sparta Sand</td><td rowspan="3">Memphis Sand</td><td>Sparta Sand</td><td>Lisbon Formation</td><td rowspan="3">Middle Claiborne aquifer
Lower Claiborne confining unit
Lower Claiborne aquifer[1]</td></tr>
<tr><td colspan="2">Cane River Formation</td><td rowspan="2">Tallahatta Formation</td><td>Zilpha Clay
Winona Sand
Tallahatta Formation</td><td>Tallahatta Formation</td></tr>
<tr><td colspan="2">Carrizo Sand</td><td colspan="2">Meridian Sand Member</td></tr>
<tr><td rowspan="4">UPPER PALEOCENE</td><td rowspan="3">Wilcox</td><td rowspan="2">Dolet Hills Formation</td><td rowspan="3">Undifferentiated</td><td colspan="2">Flour Island Formation</td><td>Wilcox Formation</td><td>Flour Island Formation</td><td rowspan="3">Undifferentiated</td><td>Hatchetigbee Formation</td><td>Middle Wilcox aquifer</td></tr>
<tr><td colspan="2">Fort Pillow Sand</td><td rowspan="2">No Wilcox deposits identified as being of Paleocene age</td><td>Fort Pillow Sand</td><td rowspan="2">Bashi Formation
Tuscahoma Sand
Nanafalia Formation</td><td rowspan="2">Lower Wilcox aquifer</td></tr>
<tr><td>Undifferentiated Naborton Formation</td><td colspan="2">Old Breast-works Formation</td><td>Old Breast-works Formation</td></tr>
<tr><td>Mid-way</td><td colspan="8">Midway Group</td><td>Midway confining unit</td></tr>
</table>

[1]Lower Claiborne aquifer includes the upper Wilcox aquifer in some portions of Mississippi.

Modified from Hosman and Weiss, 1991

study based on availability, quality, depth, and spatial distribution within the MERAS area. This report describes methods used to develop the digital-surface and thickness maps and provides a brief description of the selected hydrogeologic units and their surface altitudes and thicknesses.

Acknowledgments

The authors would like to thank the primary contributors to the effort of compiling and analyzing the large amount of data that went into this report: Jeff Brantly and Ron Seanor, USGS Louisiana Water Science Center; Mike Bradley and Jack Carmichael, USGS Tennessee Water Science Center; and Heather Welch, Jeannie Barlow, and Claire Rose, USGS Mississippi Water Science Center. The authors would also like to thank all those who had the tedious tasks of scanning and locating the geophysical logs and entering the geophysical log header information.

Previous Investigations

Several previous investigations have been conducted regionally and locally within the study area. Regional studies include the USGS Gulf Coastal Regional Aquifer-System Analysis (RASA) Program conducted from the late 1970s to the late 1990s, which resulted in a series of reports related to the Mississippi embayment and the Gulf Coastal Plain. The RASA publications used throughout this report include those containing descriptions of the geohydrologic units of the Mississippi embayment (Hosman and Weiss, 1991) and of the stratigraphy and subsurface geology of the Cenozoic deposits in the Gulf Coastal Plain (Hosman, 1996). Other notable regional studies are by Fisk (1944), Cushing and others (1964), Krinitzsky and Wire (1964), Boswell and others (1965, 1968), Payne (1968, 1970, 1972, 1975), Hosman and others (1968), and Saucier (1994). Local studies include a set of structure maps of the geohydrologic units of the Gulf Coastal Plain in Arkansas (Petersen and others, 1985), a map of the altitude of the top of the Sparta Sand of Claiborne Group (hereafter referred to as Sparta Sand) and Memphis Sand of Claiborne Group (hereafter referred to as Memphis Sand) in Arkansas (Pugh and others, 1998), geology and ground-water resources of the Cockfield Formation of Claiborne Group (hereafter referred to as Cockfield Formation), Memphis Sand, and Fort Pillow Sand of Wilcox Group (hereafter referred to as Fort Pillow Sand) in western Tennessee (Parks and Carmichael, 1989, 1990a, 1990b), and thickness maps of the Mississippi River Valley alluvial aquifer (Arthur and Strom, 1996; Luckey and Fuller, 1985; Pugh and others, 1997; and Whitfield, 1975).

Description of Study Area

The MERAS area includes parts of the West Gulf Coastal Plain, East Gulf Coastal Plain, and Mississippi Alluvial Plain sections of the Coastal Plain physiographic province (fig. 1). The entire study area is approximately 70,000 mi^2, and land-surface altitudes range from 686 ft above National Geodetic Vertical Datum (NGVD) of 1929 in the eastern and northeastern part of the study area to 3 ft above NGVD of 1929 in the southeastern part of the study area. Several large rivers drain the MERAS area, the most prominent being the Mississippi River. The primary land use within the MERAS area is agriculture of cotton, soybeans, rice, and corn, and the primary source of irrigation is ground water from the Mississippi River Valley alluvial aquifer (Kleiss and others, 2000). The deeper, confined aquifers supply freshwater primarily to industry, domestic users, and municipalities, and to a lesser degree, locally for irrigation. Declines in ground-water levels have been a concern throughout much of the Mississippi embayment for the surficial and deeper confined aquifers.

Methods

The method used to create each digital hydrogeologic surface included interpretation of the altitude of the hydrogeologic units of interest from more than 2,600 geophysical logs, then correlation of the uppermost nine hydrogeologic units, which make up the Mississippi embayment aquifer system from the top of the Midway confining unit to land surface (Hart and Clark, 2008). The geophysical logs consisted of normal-resistivity, spontaneous potential, and natural-gamma logs and primarily were from oil and gas test wells and domestic and public-supply water wells. Geophysical logs were obtained from a variety of sources, including USGS offices in Alabama, Arkansas, Louisiana, Mississippi, Missouri, and Tennessee and the Kentucky Geological Survey in Lexington, Kentucky. Geophysical logs were chosen based on availability, quality, depth, and spatial distribution. Log datums were determined from information provided in the log headers, digital elevation models, USGS 7.5-minute topographic maps, or the USGS Ground-Water Site Inventory database (http://waterdata.usgs.gov/nwis/gwsi). Surface altitudes then were calculated for the nine hydrogeologic units of interest in the Mississippi embayment aquifer system. The top of the uppermost unit, the Mississippi River Valley alluvial aquifer, was assumed to be land surface. The interpolation method for creation of each hydrogeologic surface used in the GIS was based on the Australian National University Digital Elevation Model (ANUDEM) procedure developed by Hutchinson (1989). The ANUDEM procedure was designed principally to interpolate scattered surface-specific point elevation data and to remove spurious sinks within the data without oversmoothing well-defined surface features (Hutchinson, 1989). This interpolation method can produce high or low areas that are not supported

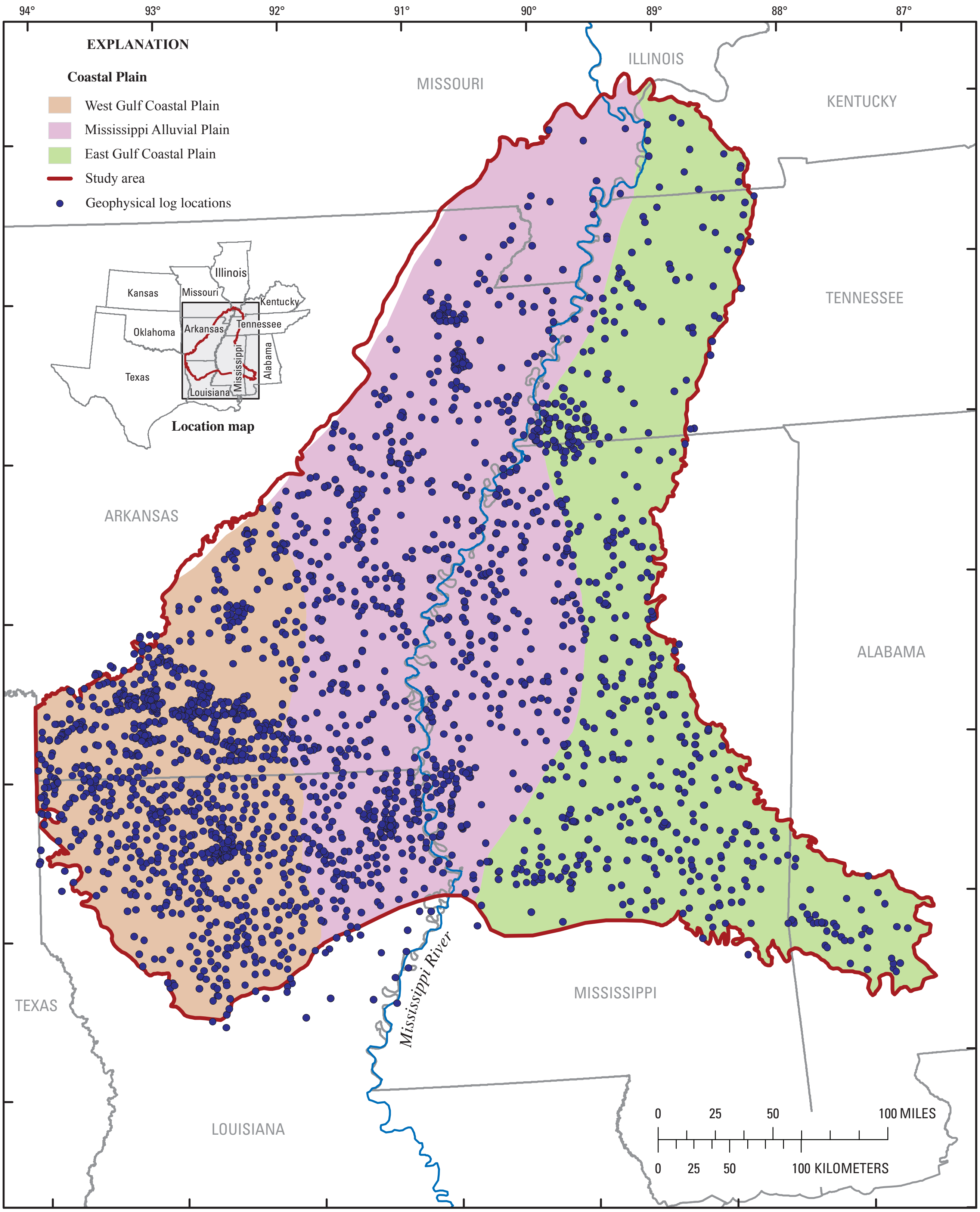

Figure 1. Locations of Coastal Plain physiographic province sections and geophysical logs in the Mississippi Embayment Regional Aquifer Study area.

by control points as nearby data trends are taken into account. Each digital hydrogeologic surface was constrained to land surface in the outcrop areas. At the outermost subcrop area of each unit, the digital hydrogeologic surface was constrained to the altitude of the underlying unit, thereby, forcing the interpolation to pinch out each unit at the boundaries. Outcrop and subcrop extents were determined from published state geologic maps (Bicker, 1969; Miller and others, 1966), other published reports (Hosman, 1982), and from geophysical-log interpretations. During the interpolation procedure, if part of a hydrogeologic unit of interest was interpolated to extend above the top of an overlying hydrogeologic unit, then the hydrogeologic unit of interest was constrained to 30 percent of the thickness between the top of the overlying unit and the top of the underlying unit. This thickness was added to the top of the underlying hydrogeologic unit to estimate the surface altitude of the over-interpolated hydrogeologic unit. This occurred primarily in subcrop to preserve 30 percent thickness within the overlying hydrogeologic unit where it was assumed the underlying hydrogeologic unit would be thinning out. Maximum and minimum interpolated surface altitudes for each digital hydrogeologic unit then were determined, and in general, maximum altitudes occurred in outcrop coinciding with land-surface altitude.

Thickness maps were constructed for each unit using the GIS to calculate the difference between the altitude of the interpreted top of the unit and the altitude of the interpreted top of the underlying unit. A thickness was calculated for the Mississippi River Valley alluvial aquifer using the difference between land surface and the interpreted altitude of the top of the hydrogeologic unit subcropping directly beneath the aquifer. A thickness for each hydrogeologic surface was calculated in Alabama to preserve thickness for layering of the finite-difference grid of the accompanying ground-water flow model, though the Claiborne Group is undifferentiated in Alabama. Maximum, minimum, mean, and median thicknesses were calculated for each digital hydrogeologic unit. A 20-percent to 80-percent relative frequency distribution was used to determine a general range of thickness for each hydrogeologic unit.

Hydrogeologic unit datasets are downloadable in grid ASCII format (http://pubs.er.usgs.gov/usgspubs/sir/sir20085098). Each hydrogeologic unit dataset contains 414 rows and 394 columns representing 1-mile grid spacing. In general, limitations of data interpolation included areas of sparse geophysical log control points, log datums not clearly defined for some logs, unknown exact extent of each hydrogeologic unit in subcrop, interpolation limitations, and values averaged over 1-mile grid spacing.

For the purposes of this report, the current digital surfaces and thicknesses of the hydrogeologic units is considered to be version 1.0. A version number may be helpful to track future updates of the interpretation of the hydrogeologic unit tops as more data are acquired and the overall understanding of the subsurface changes.

Digital Surfaces and Thicknesses of Hydrogeologic Units

Cenozoic-age and younger deposits comprise the main freshwater bearing aquifers of regional extent within the study area (Hosman and Weiss, 1991). Hydrogeologic units of interest in the MERAS area consist primarily of alternating beds of sand, silt, and clay. These units include Quaternary-age deposits of the Mississippi River Valley alluvial aquifer (composed mainly of coarse gravel, sand, and clay), the Tertiary-age deposits of the Vicksburg-Jackson confining unit, upper Claiborne aquifer, middle Claiborne confining unit, middle Claiborne aquifer, lower Claiborne confining unit, lower Claiborne aquifer, middle Wilcox aquifer, lower Wilcox aquifer, and the Midway confining unit. These units make up the aquifers and the confining units of the Mississippi embayment aquifer system.

The Claiborne Group in Alabama is undifferentiated, but could include from one to all of the following units: upper Claiborne aquifer, middle Claiborne confining unit, middle Claiborne aquifer, lower Claiborne confining unit, and lower Claiborne aquifer. Therefore, interpolated altitudes of the digital hydrogeologic surfaces between the upper Claiborne aquifer and the middle Wilcox aquifer in Alabama are not representative of actual formation altitudes but were constructed to preserve layering of the finite-difference grid for the accompanying ground-water flow model.

Table 2 gives statistical information for each hydrogeologic unit, excluding the Mississippi River Valley alluvial aquifer. The statistical information is based on the difference between the unit correlation altitudes on the geophysical logs and the altitudes of the interpolated digital hydrogeologic surfaces at the location of the geophysical log control point, referred to as the residual. Maximum and minimum residuals mainly were located in the outcrop of each formation and result from the general lack of control in these areas. The percent of unit correlation altitudes on the geophysical logs that fell within 30 ft of the interpolated digital hydrogeologic surfaces ranged from 84 to 92 percent for all surfaces (fig. 2).

The cyclical nature of alternating continental and marine depositional environments during Paleocene and Eocene Epochs of the Cenozoic Erathem controlled lithologies of units of this age in the Mississippi embayment. In general, the more sandy continental deposits are permeable and form the aquifers; the more clayey marine deposits are much less permeable and form the confining units. Intervening transgressive-regressive episodes during Paleocene and Eocene times created a shifting variety of nonmarine, marine, near marine, and deltaic environments with deposition of mixed sand, silt, and clay lithologies (Hosman and Weiss, 1991). Post-tertiary deposition in the embayment consisted primarily of terrace formation and stream aggradation as a result of the large input of sand and gravel from repeated periods of glaciation to the north during the Pleistocene Epoch, and continued fluvial deposition during the Holocene Epoch.

Table 2. Statistics for the interpolation of the hydrogeologic units.

[Count refers to the number of data points used in the statistical calculations of altitude. Mean differences (correlation altitude on the geophysical logs minus interpolated digital hydrogeologic surface altitude) is the average difference between the unit correlation altitudes on the geophysical logs and the altitudes of the interpolated digital hydrogeologic surfaces at the location of the geophysical log control point. Minimum and maximum differences are those measured between the unit correlation altitudes on the geophysical logs and the altitudes of the interpolated digital hydrogeologic surfaces; absolute mean error is the error between the unit correlation altitudes on the geophysical logs and the altitudes of the interpolated digital hydrogeologic surfaces]

Hydrogeologic unit	Count	Mean differences (feet)	Minimum differences (feet)	Maximum differences (feet)	Absolute mean error (feet)
Vicksburg-Jackson confining unit	276	-1.91	-208.83	83.19	16.57
Upper Claiborne aquifer	661	-1.23	-255.10	109.39	18.05
Middle Claiborne confining unit	1,092	-3.22	-208.37	121.51	16.58
Middle Claiborne aquifer	1,627	-1.87	-186.87	115.40	16.18
Lower Claiborne confining unit	1,433	-2.80	-353.60	188.88	19.35
Lower Claiborne aquifer	1,223	-1.16	-310.46	272.27	20.10
Middle Wilcox aquifer	1,662	-2.91	-347.09	260.39	21.18
Lower Wilcox aquifer	389	-0.48	-560.25	220.94	19.83
Midway confining unit	1,443	-1.25	-401.70	296.34	24.20

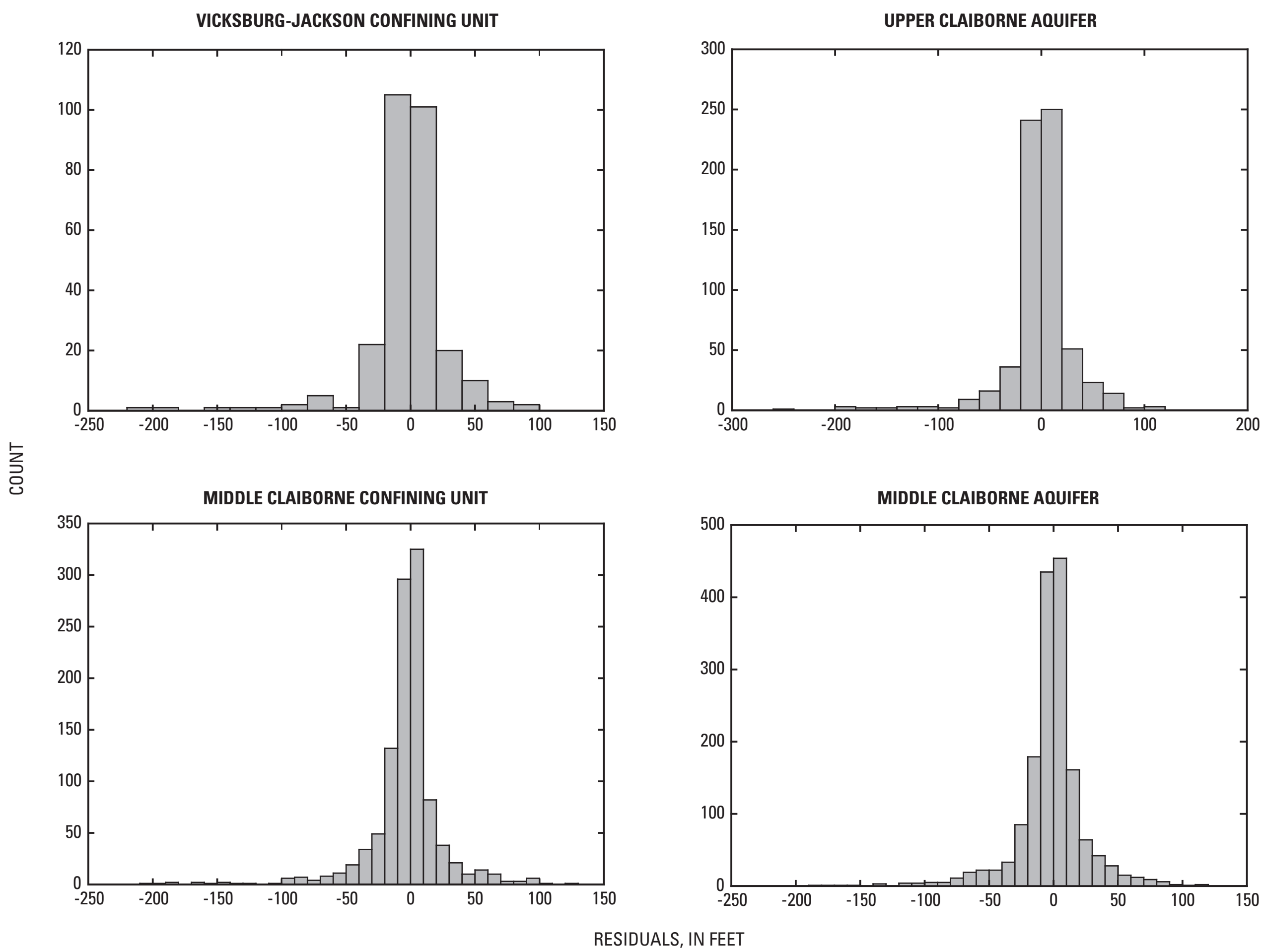

Figure 2. Residuals between the hydrogeologic unit correlation altitudes on the geophysical logs and altitudes of the interpolated digital hydrogeologic surfaces.

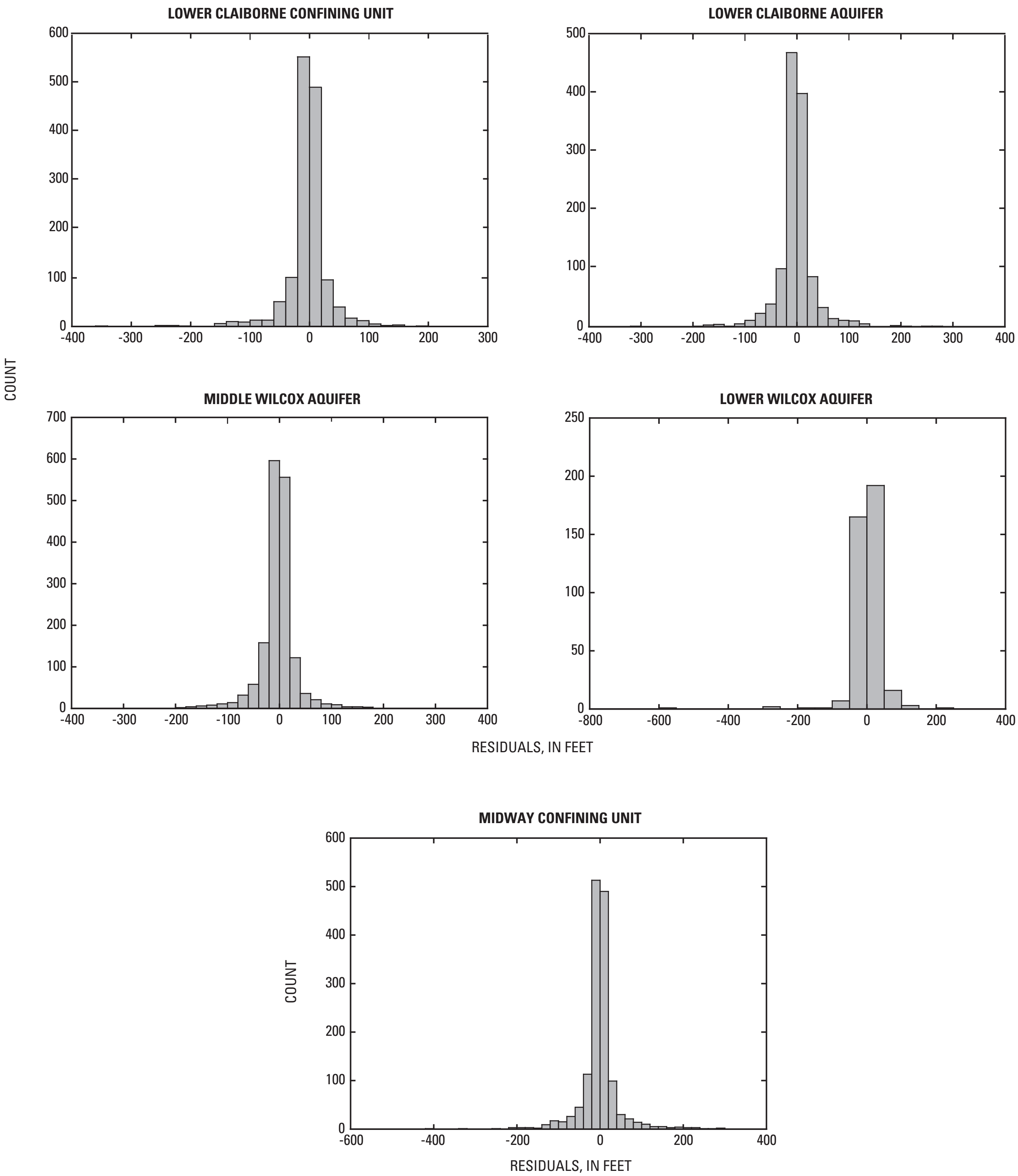

Figure 2. Residuals between the hydrogeologic unit correlation altitudes on the geophysical logs and altitudes of the interpolated digital hydrogeologic surfaces.—Continued

The Mississippi embayment lies within a plunging syncline with the axis primarily trending southward roughly parallel to the present-day Mississippi River throughout the northern half of the study area (fig. 3). There are three structural uplifts in the study area, the Sabine Uplift in eastern Texas-western Louisiana, the Monroe Uplift in southeastern Arkansas-northwestern Louisiana, and the Jackson Dome in southwestern Mississippi. These uplifts control the axis of the Mississippi embayment in the southern half of the study area, causing the axis to shift in a northwestern-southeastern direction around the Monroe Uplift. After curving to the east around the Monroe Uplift, the axis continues to parallel the present position of the Mississippi River. The Jackson Dome, located in southwestern Mississippi, structurally controls the axis on the eastern side of the syncline in the southern part of the study area. The syncline causes the beds to dip and thicken towards the axis and plunge southward, with the Cenozoic system reaching a maximum thickness of approximately 5,000 ft in the southern part of the study area (Hosman and Weiss, 1991), and most of the hydrogeologic units outcrop towards the eastern and western boundaries of the Mississippi embayment.

Several fault zones are located within the study area, and in most cases, fault throws are not large enough to completely offset the thicker hydrogeologic units (Hosman and Weiss, 1991). A series of parallel normal faults and grabens is located in southwestern Arkansas and is known as the Arkansas fault zone (fig. 3). Another fault zone, the Pickens-Gilbertown fault zone, begins in west-central Mississippi and trends southeastward across Mississippi and southwestern Alabama, appearing to be in alignment with the Arkansas fault zone (Hosman and Weiss, 1991). Further explanation of the geologic features and history of the Mississippi embayment can be found in Hosman (1996).

The Mississippi River Valley alluvial aquifer is the most widely used aquifer in the Mississippi embayment. It provides the greatest yield, which can provide wells with yields of 300 to 3,000 gallons per minute (gal/min) (Klein and others, 1950; Onellion, 1956; Bedinger and Reed, 1961; Hewitt and others, 1949) as much as 7,000 gal/min in some large wells in Louisiana (Stuart and others, 1994), and is used primarily for agriculture, particularly the irrigation of rice (Ackerman, 1996). The Mississippi River Valley alluvial aquifer section is present at land surface and covers much of the embayment area beneath the Mississippi Alluvial Plain of the Coastal Plain physiographic province. The next most widely used aquifer is the middle Claiborne aquifer, which can provide wells with yields of 100 to 500 gal/min (as much as 1,500 gal/min in the western Tennessee area), and is used primarily for industry and public supply (McKee and Hays, 2002). The middle Claiborne aquifer lies several hundred feet beneath land surface. A generalized west to east section through the Mississippi embayment showing the primary Tertiary-age and younger hydrogeologic unit of the Mississippi embayment aquifer system is shown in figure 4.

Mississippi River Valley Alluvial Aquifer

The Mississippi River Valley alluvial aquifer (hereafter referred to as the alluvial aquifer) consists of alluvial deposits of mostly Holocene age (table 1). The materials that make up the alluvial aquifer range in size from coarse gravel to clay, and commonly grade finer upward to sand, silt, and clay. Coarse sand and gravel deposits primarily are located in the basal part of the alluvial aquifer (Hosman and Weiss, 1991; Hosman, 1996). The upper part of the alluvial aquifer primarily consists of clay, silt, and fine-grained sand.

The alluvial aquifer is present in the southeastern part of Missouri, the northeastern part of Louisiana, the western edge of Mississippi, and extreme western Tennessee and Kentucky near the Mississippi River, and throughout most of eastern Arkansas (fig. 5). The interpreted thickest sections of the alluvial aquifer are located in southeastern Missouri and northwestern Mississippi; in these areas, the unit can reach thicknesses as much as 290 ft (fig. 5). However, the alluvial aquifer, relative to other hydrogeologic units in the Mississippi embayment, is a relatively thin unit. The interpreted thinnest sections of the alluvial aquifer are located along the edge of the outcrop, mainly in the northwestern part of the study area and along Crowleys Ridge in Arkansas (fig. 5). The average interpreted thickness of the alluvial aquifer is approximately 130 ft and the median interpreted thickness is 130 ft. The thickness of the alluvial aquifer generally ranges from 110 ft to 150 ft.

Vicksburg-Jackson Confining Unit

The Vicksburg-Jackson confining unit is composed of marine clay, marl, and limestone of the Jackson Group and the Vicksburg Group (Vicksburg Formation in Texas). The predominant lithology of the confining unit is clay with some sands that are of no consequence to the regional aquifer systems. A substantial time break occurs within the Vicksburg-Jackson confining unit separating the lower part (Jackson Group) of Eocene age from the upper part (Vicksburg Group) of Oligocene age (Renken, 1998). Biota age differences in the units are the main basis for the verification of the time break—stratigraphically, the lithology is the same.

Erosion of the Vicksburg-Jackson confining unit near the northeastern Louisiana-west-central Mississippi and northern Arkansas-western Tennessee area causes a gap in the subcrop of the unit, making it the only hydrogeologic unit in the Mississippi embayment aquifer system that is not one continuous body (Hosman and Weiss, 1991). The Vicksburg-Jackson confining unit is located mainly in the central part of the study area, covering the eastern and southeastern part of Arkansas (fig. 6). The confining unit is also present along the southern part of the study area, extending from central Louisiana, thickening through the west-central part of Mississippi, and thinning into Alabama. The highest altitudes of the interpreted top of the Vicksburg-Jackson confining unit, over

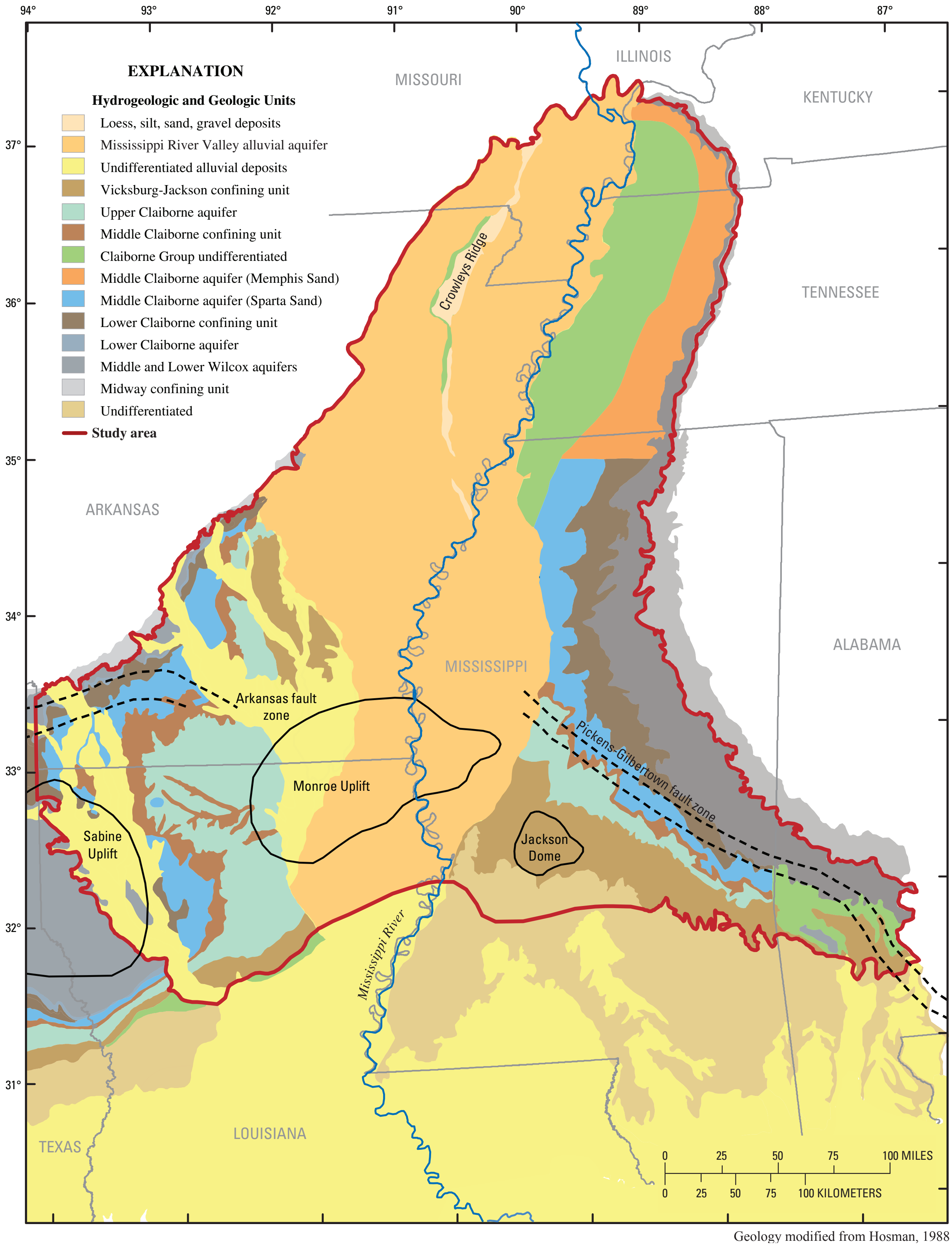

Figure 3. Surficial geology of the Mississippi Embayment Regional Aquifer Study area.

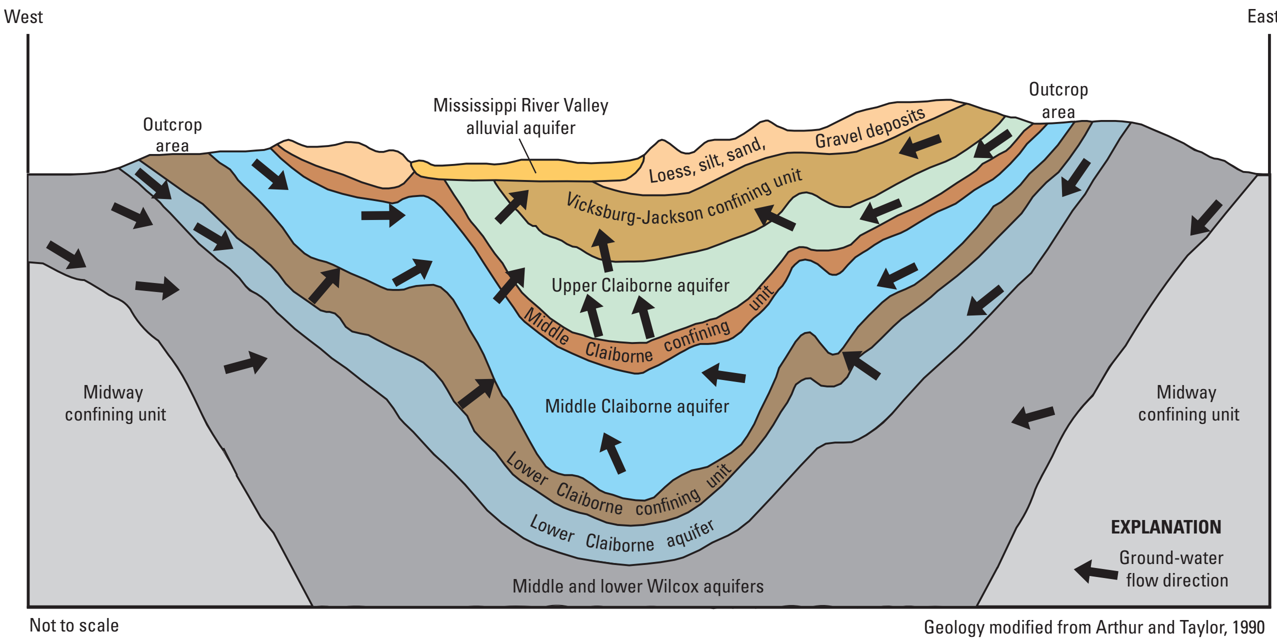

Figure 4. Generalized section of the hydrogeologic and geologic units within the Mississippi Embayment Regional Aquifer Study area.

565 ft above NGVD of 1929, are located in the outcrop area in central Mississippi. The lowest altitudes of the interpreted top of the unit, approximately 365 ft below NGVD of 1929, are located in west-central Mississippi at the southern edge of the study area (fig. 6).

The interpreted thickest sections of the Vicksburg-Jackson confining unit, approximately 730 ft, are located in the southern part of the study area where all of the units began the transition of dipping sharply towards the Gulf of Mexico (fig. 7). The interpreted thinnest sections are located where the Vicksburg-Jackson confining unit subcrops beneath the alluvial aquifer or outcrops. The average interpreted thickness of the Vicksburg-Jackson confining unit is approximately 195 ft and the median interpreted thickness is approximately 155 ft. The thickness of the Vicksburg-Jackson confining unit generally ranges from 45 ft to 330 ft.

Upper Claiborne Aquifer

The upper Claiborne aquifer underlies the Vicksburg-Jackson confining unit, where present, or the alluvial aquifer figs. (4 and 8), and consists of Eocene-age interbedded fine sand, silt, clay, and some lignite. Sand beds are thicker near the base of the aquifer, and the most productive layers are found in the Cockfield Formation (table 1). Because of the limited extent of fluvial deposition that created this unit and subsequent removal by erosion in some areas, the aquifer provides only a small supply of ground water (Lloyd and Lyke, 1995).

The extent of the upper Claiborne aquifer is similar in shape to that of the MERAS area, with a thinner west to east section extending up the embayment and widening towards the southern part of the study area (fig. 8). The highest altitudes of the interpreted top of the aquifer are over 520 ft above NGVD of 1929 and are located in central Mississippi in the southeastern part of the study area. The lowest interpreted altitudes of the top of the aquifer are more than 875 ft below NGVD of 1929 and are located at the southern edge of the study area along the axis of the embayment. The interpreted thickest sections of the upper Claiborne aquifer, approximately 825 ft, are located in the southern part of the study area where all of the units begin to sharply dip toward the Gulf of Mexico (fig. 9). The interpreted thinnest sections are located where the upper Claiborne aquifer subcrops beneath the alluvial aquifer or where it crops out. The average interpreted thickness of the upper Claiborne aquifer is approximately 190 ft and the median interpreted thickness is approximately 150 ft. The thickness of the upper Claiborne aquifer generally ranges from 55 ft to 290 ft.

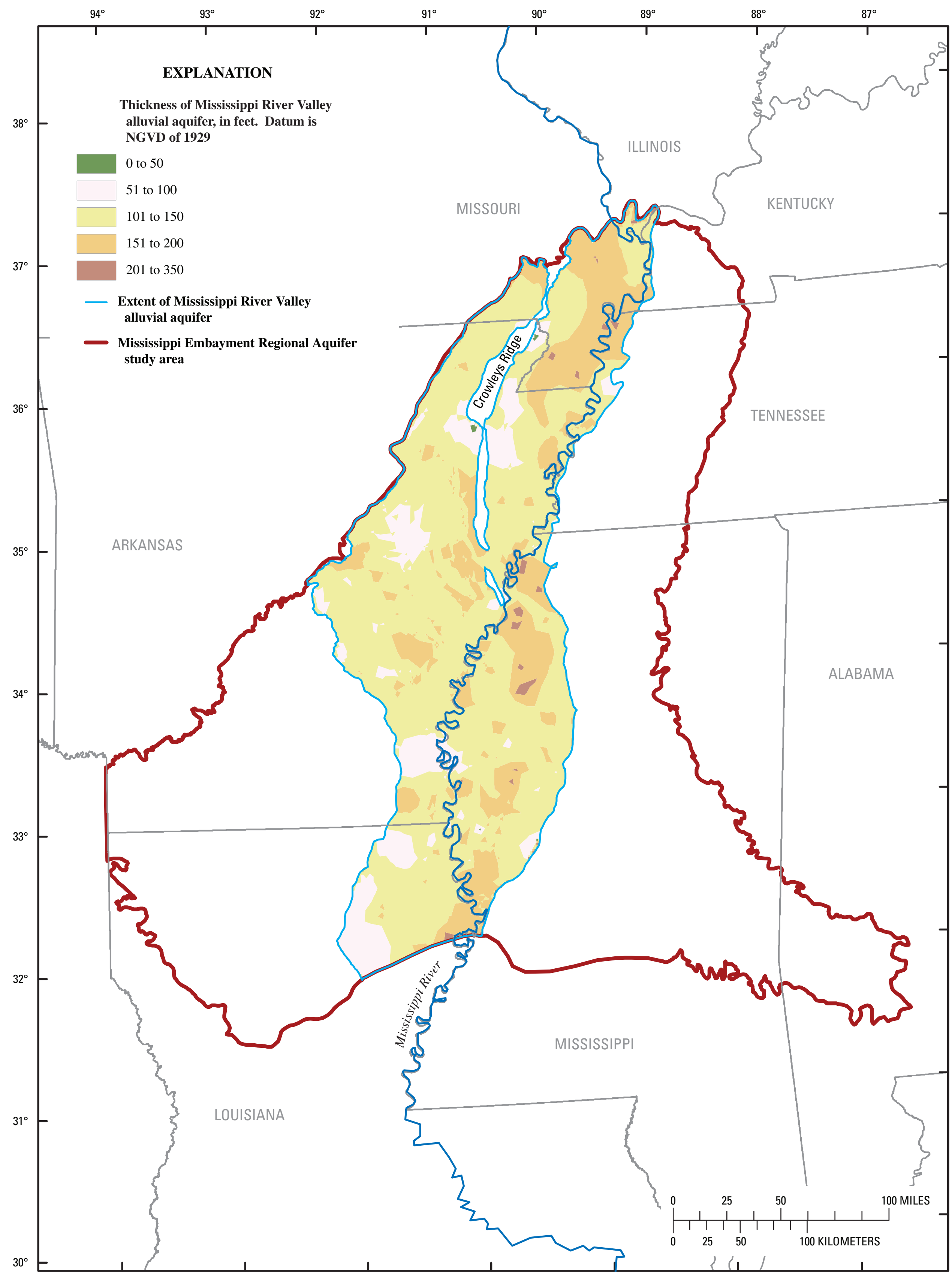

Figure 5. Thickness of the Mississippi River Valley alluvial aquifer.

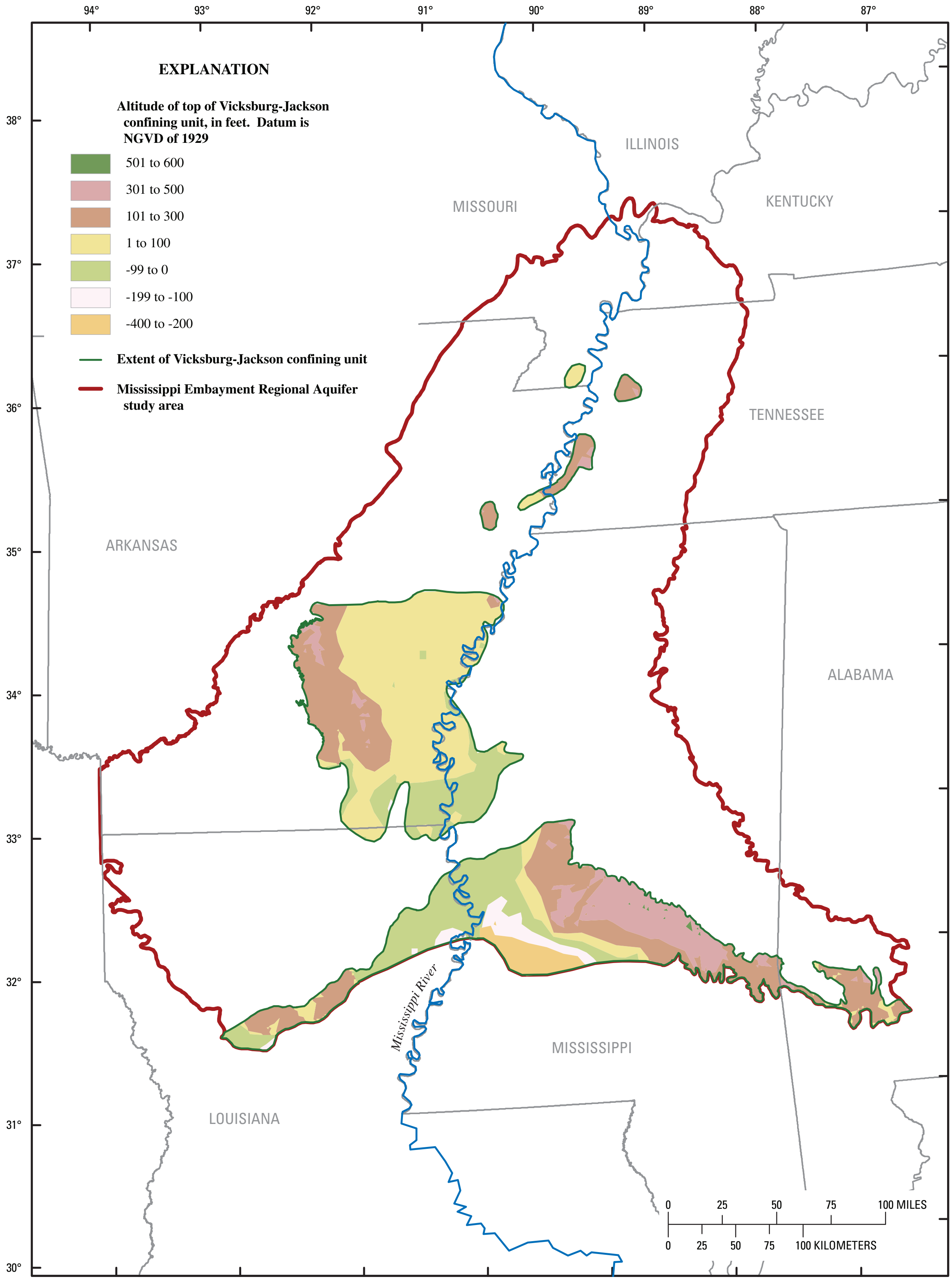

Figure 6. Altitude of top of Vicksburg-Jackson confining unit.

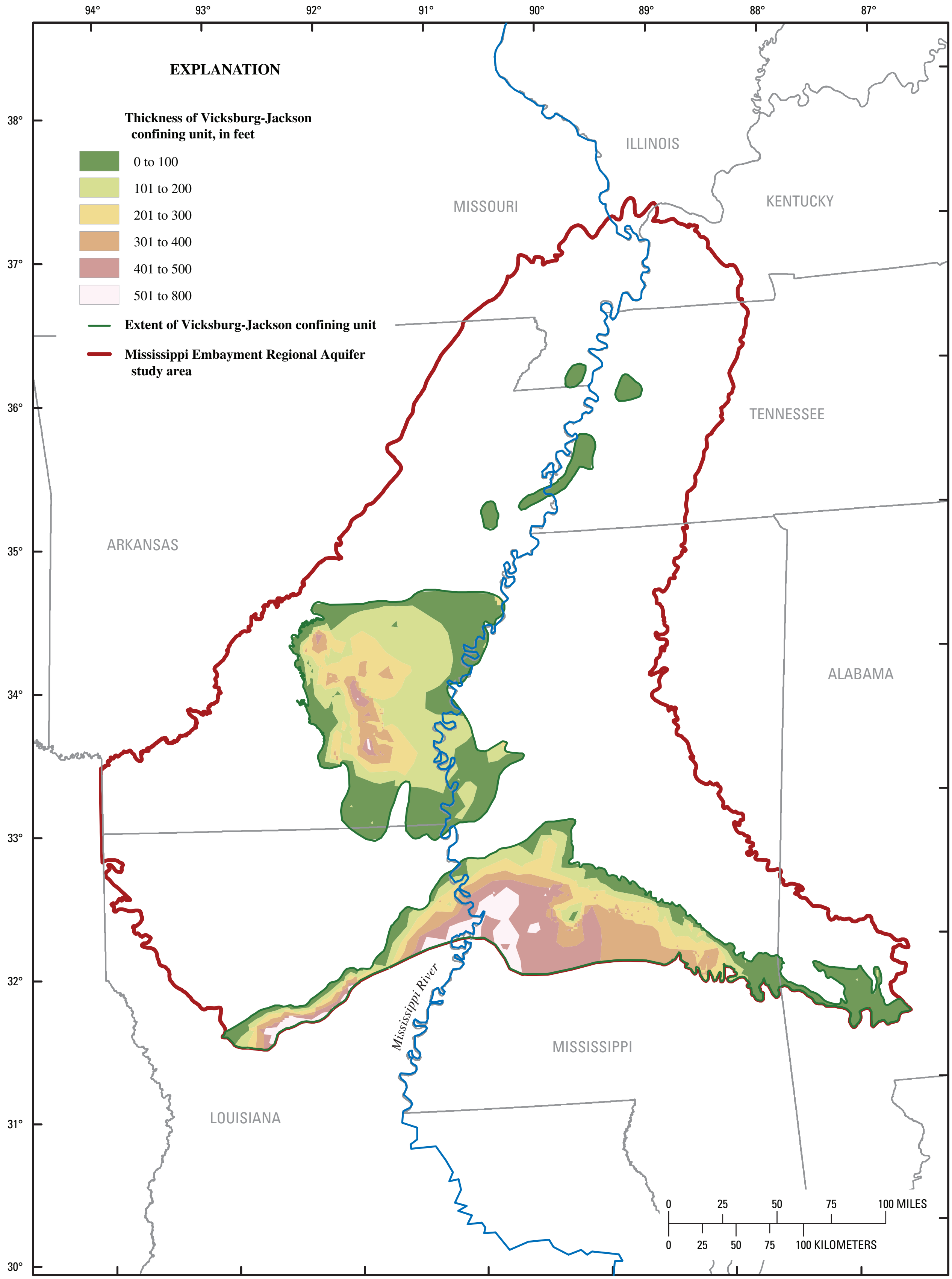

Figure 7. Thickness of Vicksburg-Jackson confining unit.

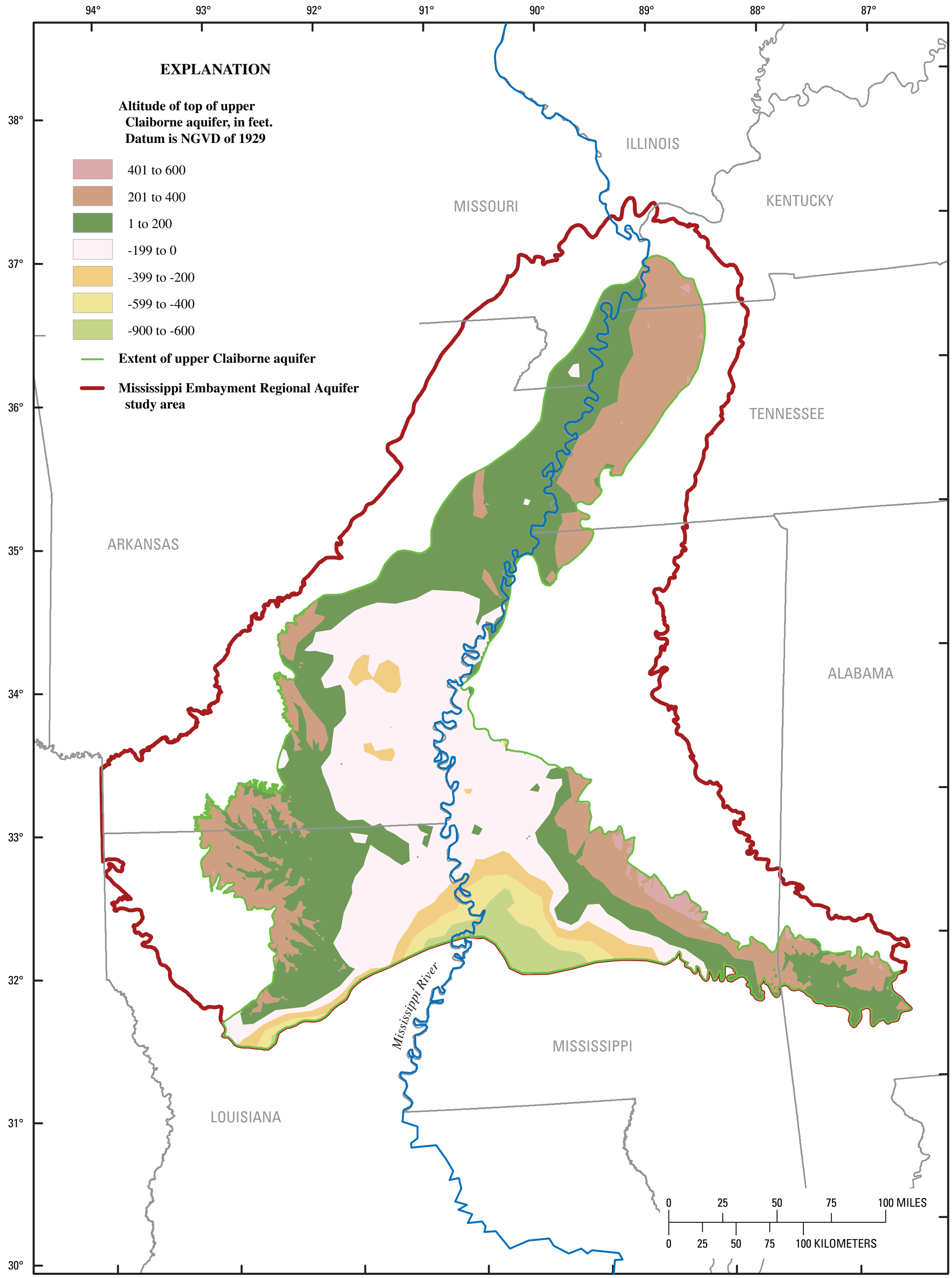

Figure 8. Altitude of top of upper Claiborne aquifer.

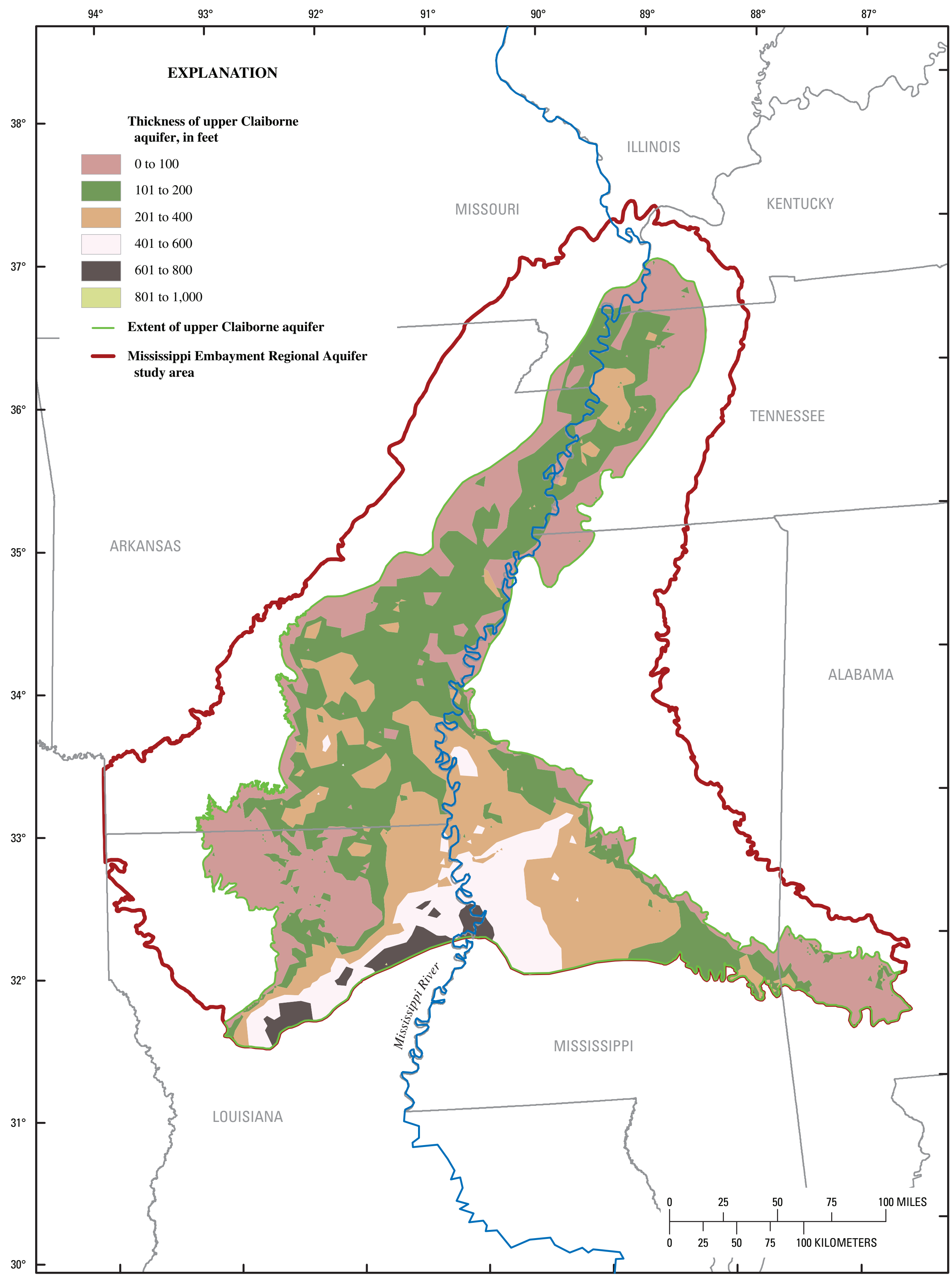

Figure 9. Thickness of upper Claiborne aquifer.

Middle Claiborne Confining Unit

The middle Claiborne confining unit underlies the upper Claiborne aquifer (fig. 4; table 1) and consists of extensive marine clay. This unit is composed of thick beds of clay of the Cook Mountain Formation, which serves as the lower confining unit to the upper Claiborne aquifer thus retarding vertical movement of ground water between the upper and lower Claiborne aquifers in the Mississippi embayment aquifer system.

The middle Claiborne confining unit is similar in shape to that of the upper Claiborne aquifer, but larger in area (fig. 10). The highest altitudes of the interpreted top of the confining unit, located in the northeastern and southeastern part of the middle Claiborne confining unit extent, are approximately 540 ft above NGVD of 1929. The lowest altitudes of the interpreted top of the confining unit are approximately 1,460 ft below NGVD of 1929 and are located in the southern part of the study area. The thickest interpreted sections of the middle Claiborne confining unit, approximately 420 ft, are located in the southwestern part of the study area in central Arkansas and west-central Louisiana (fig. 11). The interpreted thinnest sections are located where the middle Claiborne confining unit subcrops beneath the alluvial aquifer or where it crops out. The middle Claiborne confining unit has an average interpreted thickness of approximately 120 ft and a median interpreted thickness of approximately 125 ft. The thickness of the middle Claiborne aquifer generally ranges from 70 ft to 160 ft.

Middle Claiborne Aquifer

The middle Claiborne aquifer underlies the middle Claiborne confining unit (fig. 4; table 1). This aquifer is a major source of ground water in the Mississippi embayment and the most extensively used of the Tertiary-age aquifers. The aquifer primarily consists of the Sparta Sand in the southern part of the study area and the Memphis Sand in the northern part of the study area, both of which are composed of continentally derived sands with little interbedded clay. These sand beds are of varying thickness and extent, and because of the limited extent of clay layers, they allow large amounts of water to be withdrawn from the aquifer. In the northern part of the study area, the underlying lower Claiborne confining unit undergoes a facies transition with the middle Claiborne aquifer and the lower Claiborne aquifer merges to become the Memphis Sand (Hosman and Weiss, 1991).

The middle Claiborne aquifer extends to the northeastern edge of the study area in Tennessee and Kentucky and to the southern edge of the study area in Louisiana, Mississippi, and Alabama, occurring almost entirely throughout the study area (fig. 12). The highest altitudes of the interpreted top of the aquifer, approximately 655 ft above NGVD of 1929, are located where the middle Claiborne aquifer outcrops at the eastern edge of the study area. The lowest altitudes of the interpreted top of the aquifer, approximately 1,660 ft below NGVD of 1929, are located where the middle Claiborne aquifer dips sharply off toward the Gulf of Mexico. The middle Claiborne aquifer is the thickest aquifer of importance in the Mississippi embayment; it is the second most widely used aquifer of the Cenozoic deposits and second in use only to the alluvial aquifer. The interpreted thickest sections of the middle Claiborne aquifer are approximately 1,890 ft, and are located in the southern part of the study area in western Mississippi along the axis of the embayment (fig. 13). The interpreted thinnest sections are located where the middle Claiborne aquifer subcrops beneath the alluvial aquifer or where it crops out. The middle Claiborne aquifer has an average interpreted thickness of approximately 820 ft and a median interpreted thickness of approximately 805 ft. The thickness of the middle Claiborne aquifer generally ranges from 475 ft to 1,125 ft.

Lower Claiborne Confining Unit

The lower Claiborne confining unit separates the middle Claiborne aquifer from the lower Claiborne aquifer (fig. 4). Much of the lower Claiborne confining unit consists of the Cane River Formation in Arkansas and Louisiana or its equivalents, the Zilpha Clay of Claiborne Group, Winona Sand of Claiborne Group, and Tallahatta Formation of Claiborne Group in Mississippi (table 1). These units change facies and become more sandy updip and typically are included in the middle Claiborne and lower Claiborne aquifers in parts of Arkansas, Kentucky, Missouri, and Tennessee where the confining unit is absent. Where more clay-rich downdip, the lower Claiborne confining unit retards the vertical movement of water between the two aquifers.

The lower Claiborne confining unit extends from the facies transition to the southern edge of the study area (fig 14). The highest altitudes of the interpreted top of the confining unit are located along the eastern and western outcrop extents. In these areas, the top of the unit is interpreted to attain altitudes approximately 615 ft above NGVD of 1929. The lowest interpreted altitudes of the lower Claiborne confining unit, approximately 2,540 ft below NGVD of 1929, are located at the southern edge of the study area. The interpreted thickest sections of the lower Claiborne confining unit are approximately 1,230 ft, and are located in the southern part of the study area in central Mississippi (fig. 15). The interpreted thinnest sections are located where the lower Claiborne confining unit subcrops beneath the alluvial aquifer or where it crops out. The lower Claiborne confining unit has an average interpreted thickness of approximately 350 ft and a median interpreted thickness of approximately 340 ft. The thickness of the lower Claiborne confining unit generally ranges from 220 ft to 475 ft.

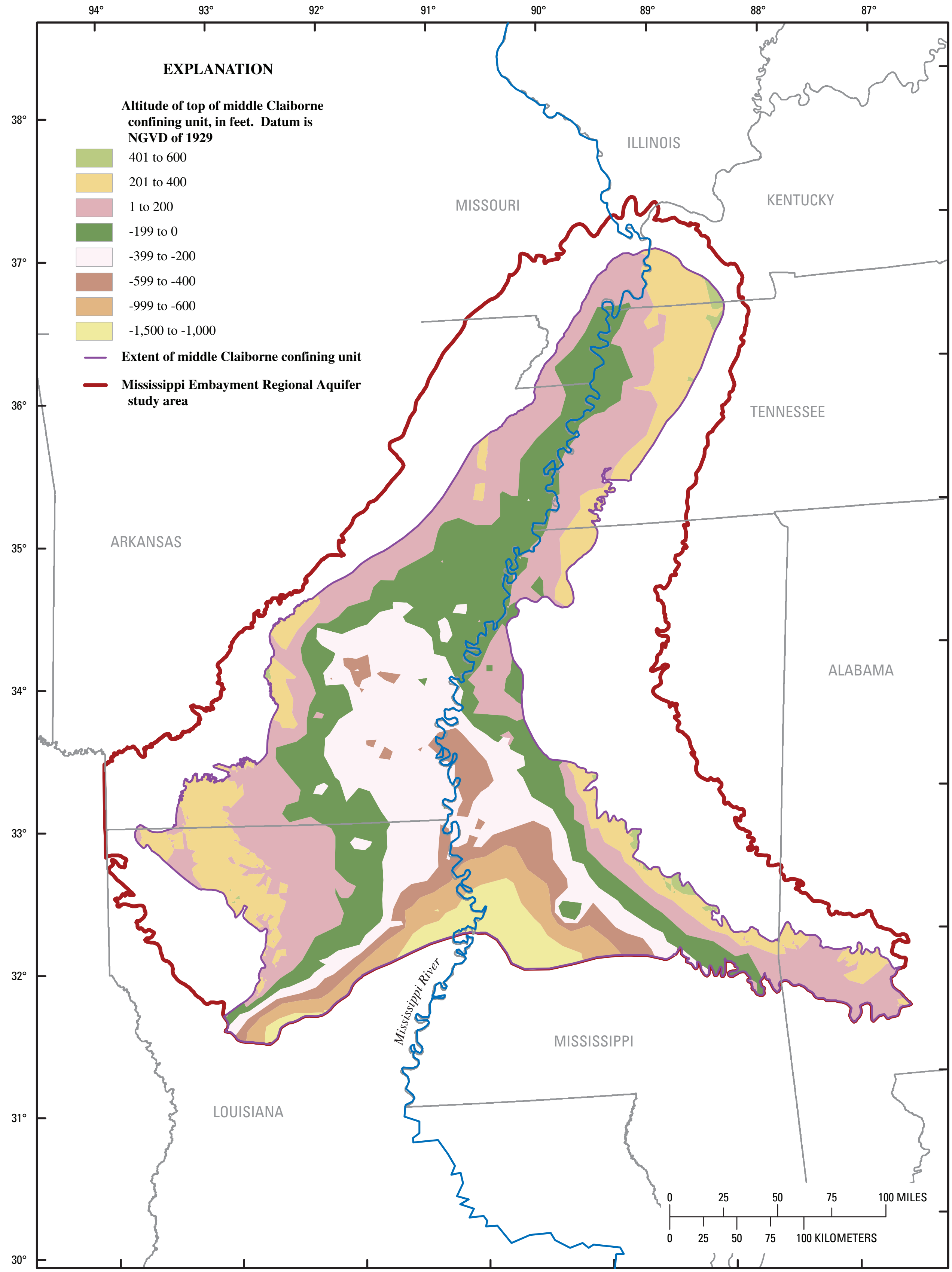

Figure 10. Altitude of top of middle Claiborne confining unit.

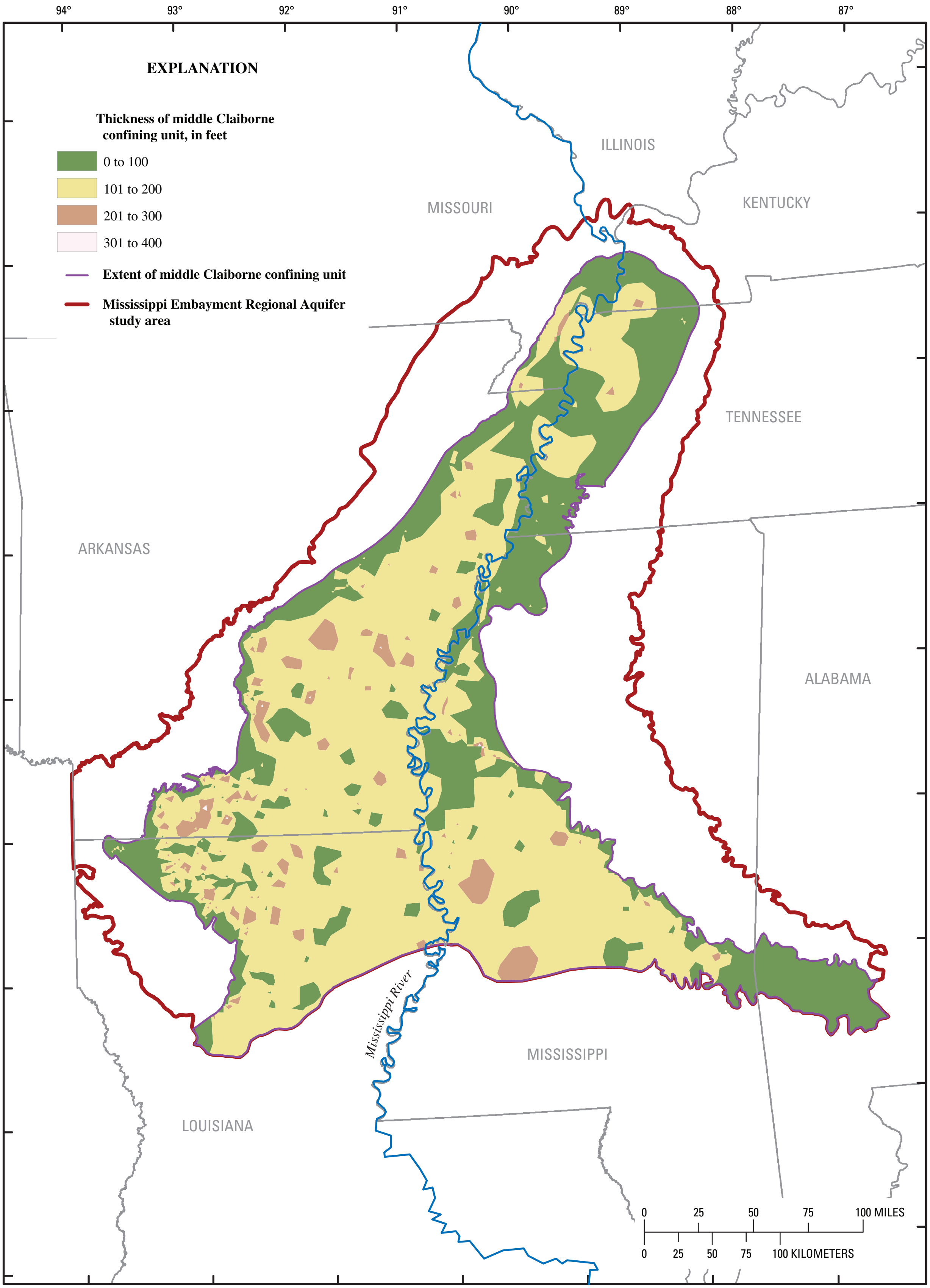

Figure 11. Thickness of middle Claiborne confining unit.

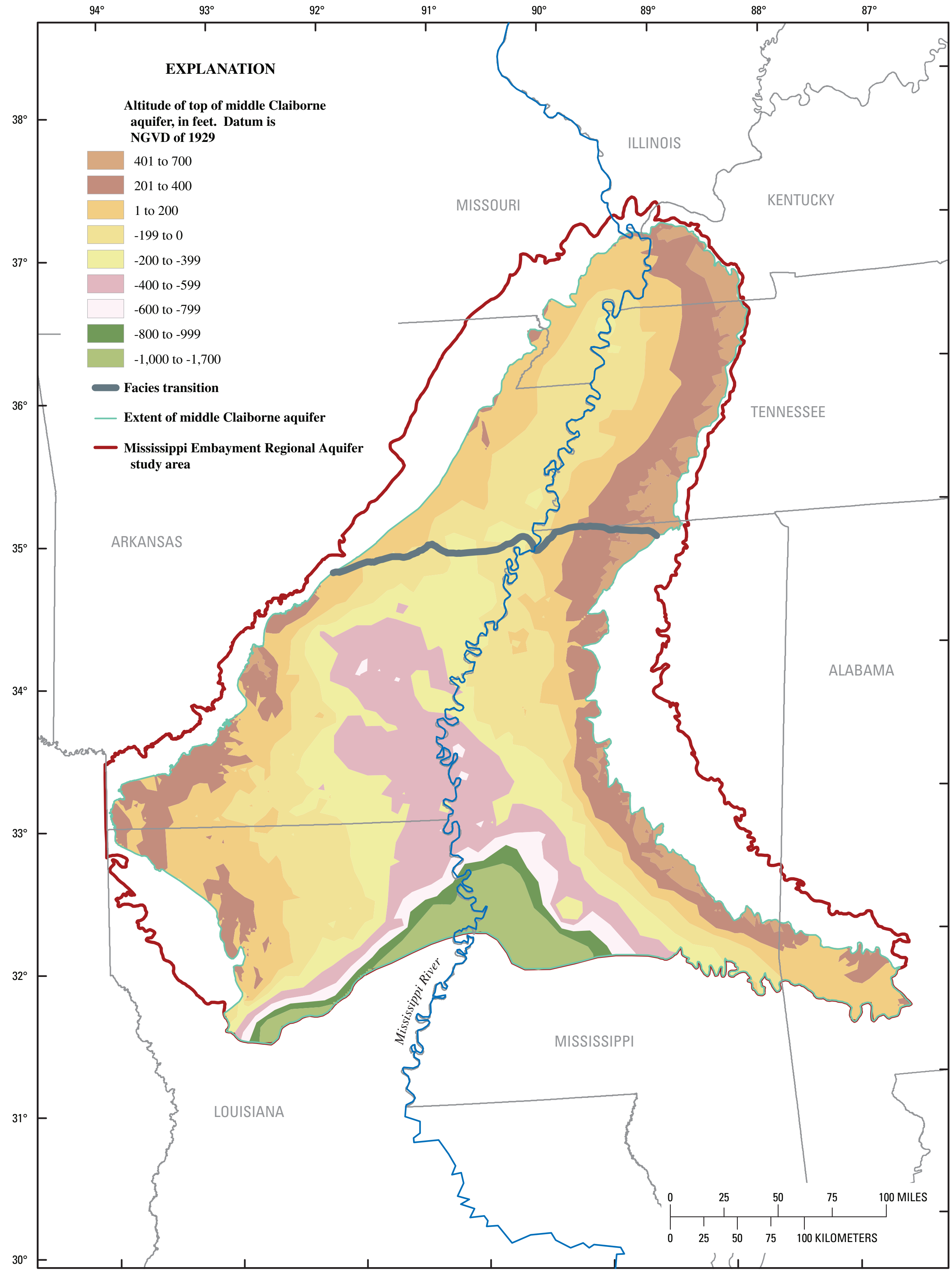

Figure 12. Altitude of top of middle Claiborne aquifer.

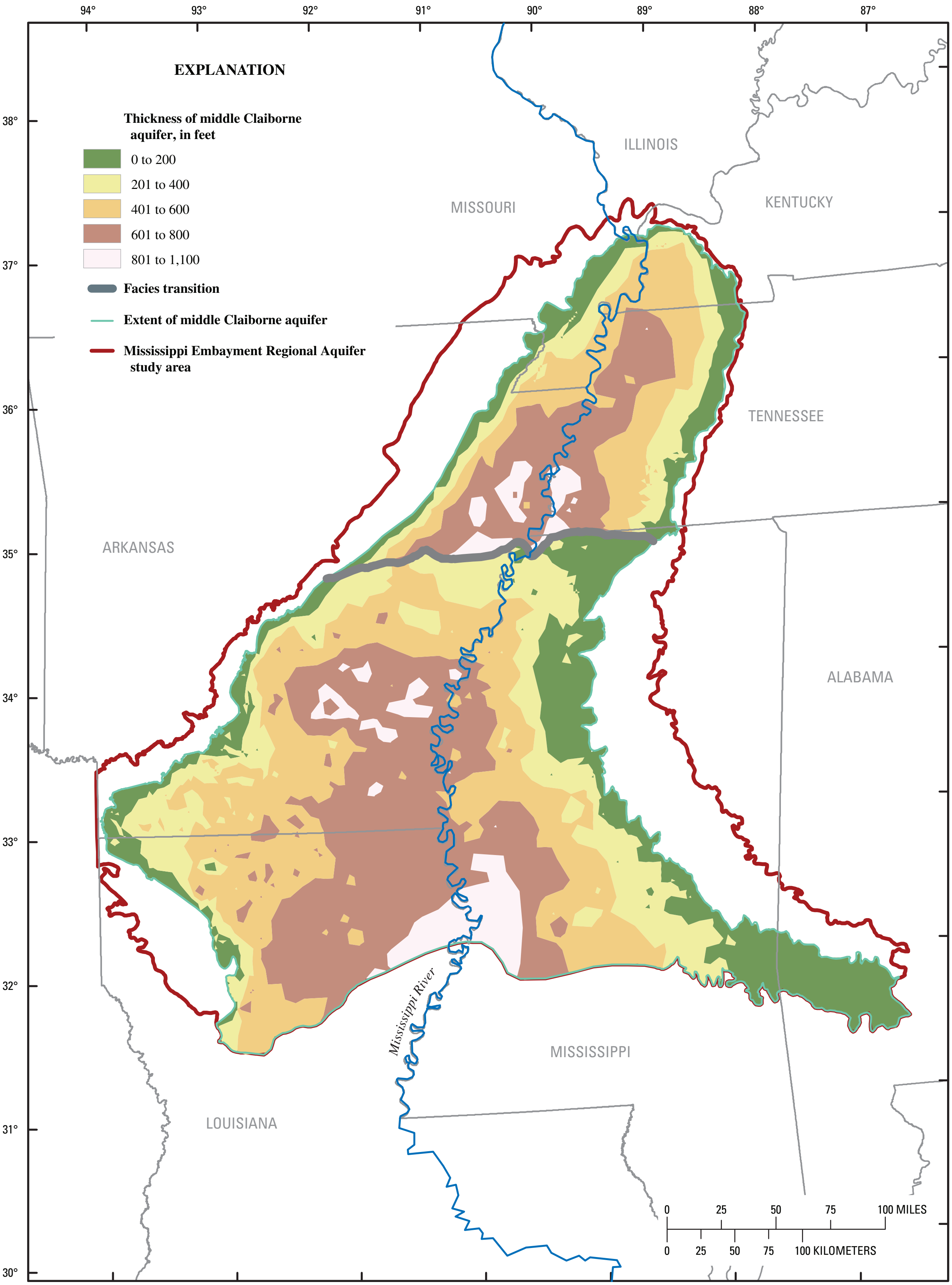

Figure 13. Thickness of middle Claiborne aquifer.

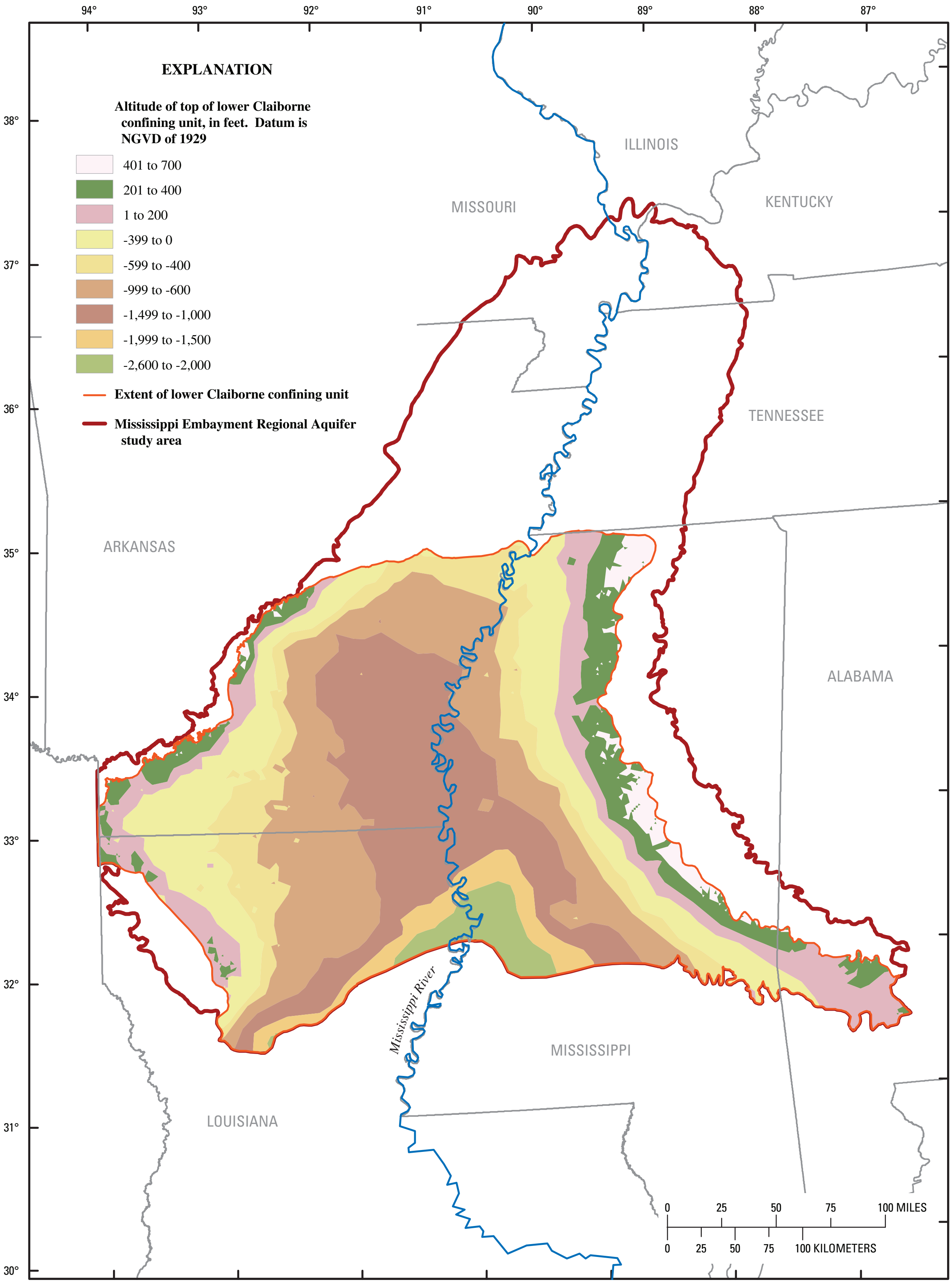

Figure 14. Altitude of top of lower Claiborne confining unit.

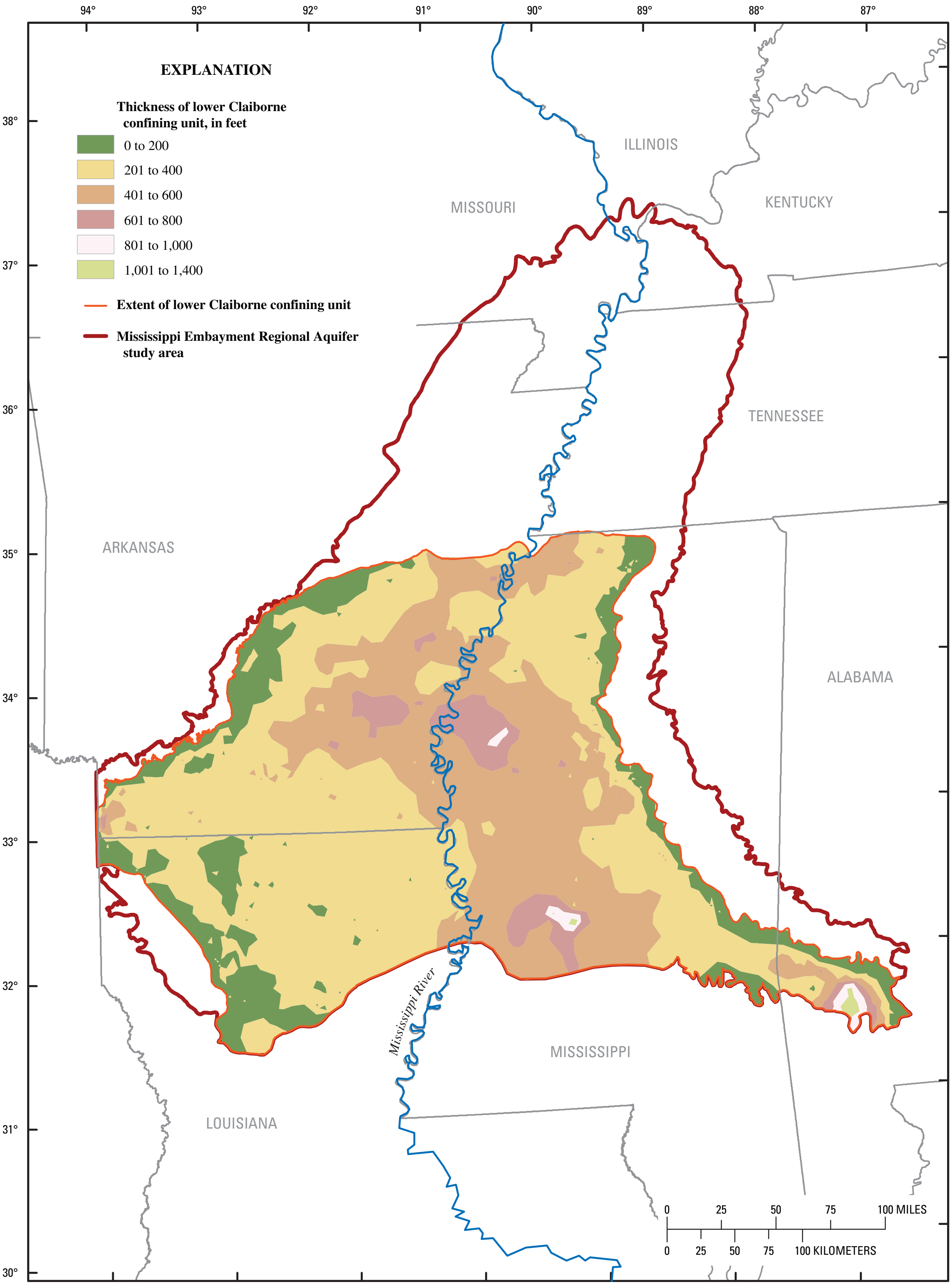

Figure 15. Thickness of lower Claiborne confining unit.

Lower Claiborne Aquifer

Most of the lower Claiborne aquifer comprises the Carrizo Sand of Claiborne Group in Arkansas and Louisiana and its equivalent or the Meridian Sand Member of Claiborne Group in Mississippi (table 1). The aquifer consists of thick beds of fine to coarse sand interbedded with thin layers of clay and silt.

The extent of the lower Claiborne aquifer is similar to that of the lower Claiborne confining unit, except the lower Claiborne aquifer outcrop extends farther on the eastern side of the study area (fig. 16). The highest altitudes of the interpreted top of the lower Claiborne aquifer, approximately 615 ft above NGVD of 1929, are located on the eastern edge in the outcrop. The lowest altitudes of the interpreted top of the aquifer, approximately 3,100 ft below NGVD of 1929, are located at the southern edge of the study area along the axis of the embayment. The interpreted thickest sections of the lower Claiborne aquifer are approximately 405 ft, and are located in the central part of the study area in east-central Arkansas (fig. 17). Overall, the lower Claiborne aquifer is a relatively thin unit and one of the thinnest units in the Mississippi embayment aquifer system. The interpreted thinnest sections are located where the lower Claiborne aquifer subcrops beneath the alluvial aquifer or where it crops out. The lower Claiborne aquifer has an average interpreted thickness of approximately 130 ft and a median interpreted thickness of approximately 125 ft. The thickness of the lower Claiborne aquifer generally ranges from 50 ft to 195 ft.

Middle Wilcox Aquifer

The middle Wilcox aquifer primarily consists of the Hatchetigbee Formation of Wilcox Group in Alabama, the undifferentiated geologic units in southern Arkansas and Mississippi, the Dolet Hills Formation of Wilcox Group in Louisiana, and the Flour Island Formation of Wilcox Group in northeastern Arkansas, Missouri, and Tennessee (table 1). The aquifer is composed predominantly of thin interbedded layers of sand, silt, and clay (Arthur and Taylor, 1998). The sand beds are thin and discontinuous causing resistance to vertical flow of water and limiting the use of this unit as a major source of ground water. The Flour Island Formation of Wilcox Group consists of silt and clay in northeastern Arkansas, Missouri, and Tennessee and forms a confining unit separating the lower Claiborne aquifer from the underlying lower Wilcox aquifer.

The middle Wilcox aquifer extends throughout most of the study area except for a thin section along the northwestern edge (fig. 18). The highest altitudes of the interpreted top of the middle Wilcox aquifer are approximately 630 ft above NGVD of 1929 and are located in the outcrop along the eastern edge of the study area. The lowest altitudes of the interpreted top of the aquifer are approximately 3,345 ft below NGVD of 1929 and are located at the southern edge of the study area along the axis of the embayment. The thickest interpreted sections of the middle Wilcox aquifer are approximately 2,765 ft, and are located along the southern edge of the study area (fig. 19). The interpreted thinnest sections are located where the middle Wilcox aquifer subcrops beneath the alluvial aquifer or where it crops out. The middle Wilcox aquifer has an average interpreted thickness of approximately 710 ft and a median interpreted thickness of approximately 505 ft. The thickness of the middle Wilcox aquifer generally ranges from 225 ft to 1,125 ft.

Lower Wilcox Aquifer

The lower Wilcox aquifer underlies the middle Wilcox aquifer and consists of all the units below the middle Wilcox aquifer to the Midway confining unit in Alabama, northeast Arkansas, Kentucky, Missouri, Mississippi, and Tennessee. The lower Wilcox aquifer also consists of the undifferentiated Wilcox units in Arkansas, Louisiana, and Mississippi (fig. 4; table 1). The sand deposits for this unit tend to be thicker, more massive, and more continuous than those of the middle Wilcox aquifer. In the northern part of the Mississippi embayment, a massive mostly sand bed, the Fort Pillow Sand of Wilcox Group of Arkansas, Missouri, and Tennessee (Moore and Brown, 1969), occurs in the lower to middle part of the Wilcox Group (table 1), and is distinguished from the middle Wilcox aquifer on a geophysical log by a substantial increase in resistivity. The lower Wilcox aquifer consists of fluvial sand similar to that in parts of the present-day Mississippi flood plain (Lloyd and Lyke, 1995). The sand primarily is hydraulically interconnected laterally.

The lower Wilcox aquifer extends into the northern part of the study area in sections of Arkansas, Kentucky, Missouri, and Tennessee, and continues along the eastern edge of the study area through central Mississippi into Alabama (fig. 20). A persistent sand unit present in the undifferentiated geologic units in Mississippi was used as the top of the lower Wilcox aquifer. The highest altitudes of the interpreted top of the lower Wilcox aquifer, approximately 555 ft above NGVD of 1929, are located in the outcrop along the eastern edge of the study area. The lowest altitudes of the interpreted top of the aquifer, approximately 2,320 ft below NGVD of 1929, are located along the central part of the study area in eastern Arkansas along the present day Mississippi River. The interpreted thickest sections of the lower Wilcox aquifer are approximately 1,770 ft, and are located in the southern part of the study area in central Mississippi (fig. 21). The interpreted thinnest sections are located where the lower Wilcox aquifer subcrops beneath the alluvial aquifer or where it crops out. The lower Wilcox aquifer has an average interpreted thickness of approximately 245 ft and a median interpreted thickness of approximately 230 ft. The thickness of the lower Wilcox aquifer generally ranges from 65 ft to 350 ft.

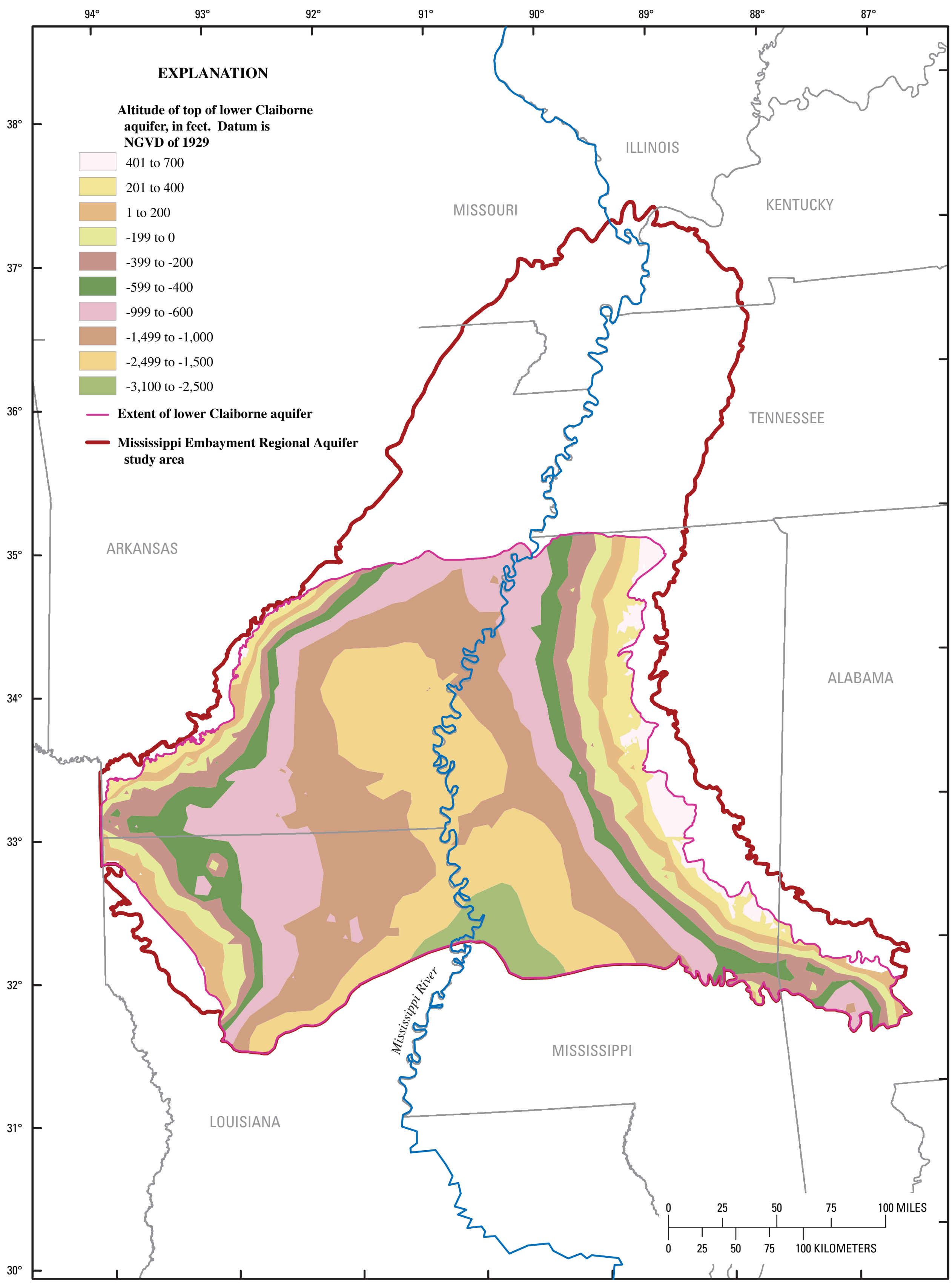

Figure 16. Altitude of top of lower Claiborne aquifer.

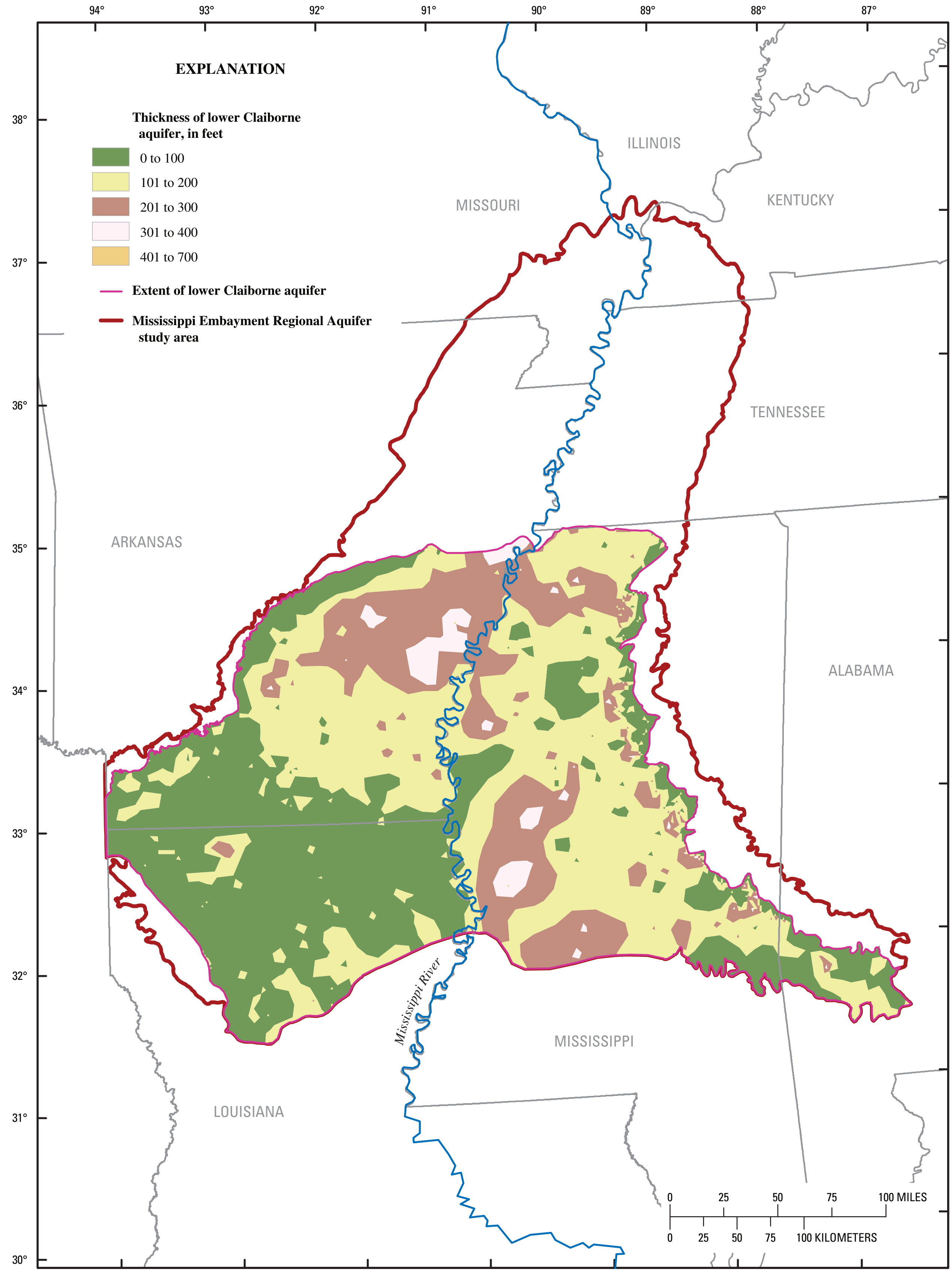

Figure 17. Thickness of lower Claiborne aquifer.

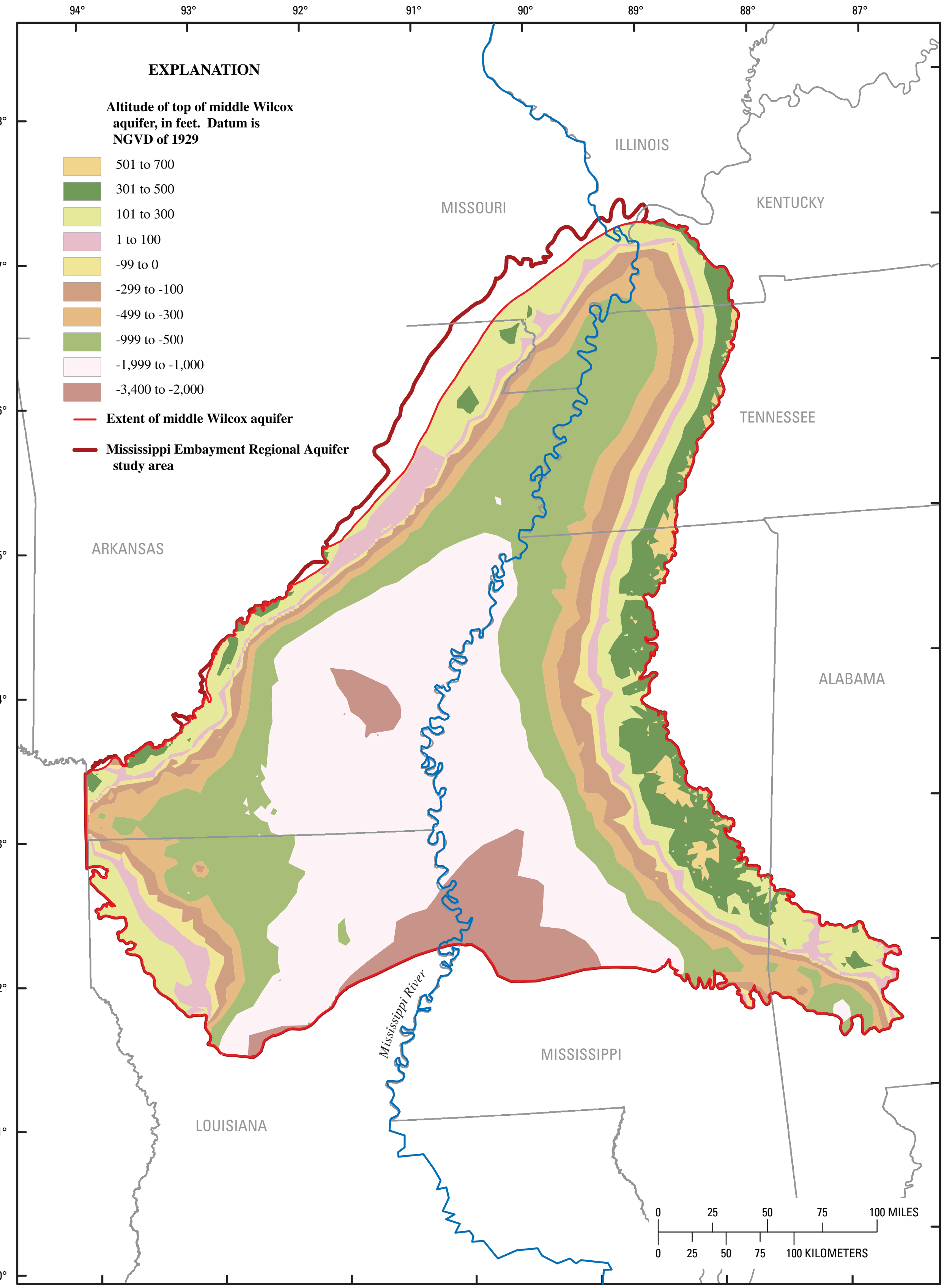

Figure 18. Altitude of top of middle Wilcox aquifer.

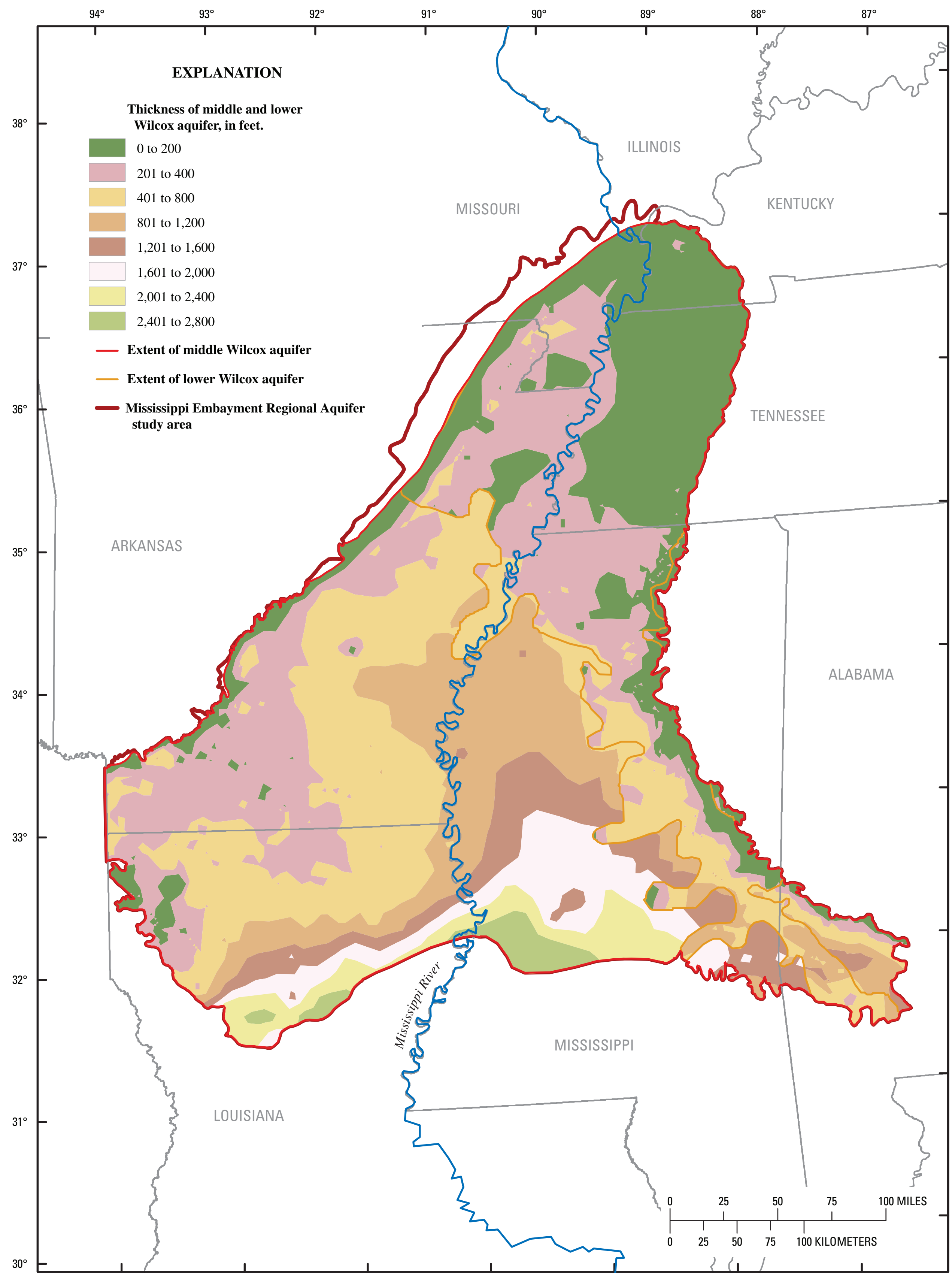

Figure 19. Thickness of middle and lower Wilcox aquifer.

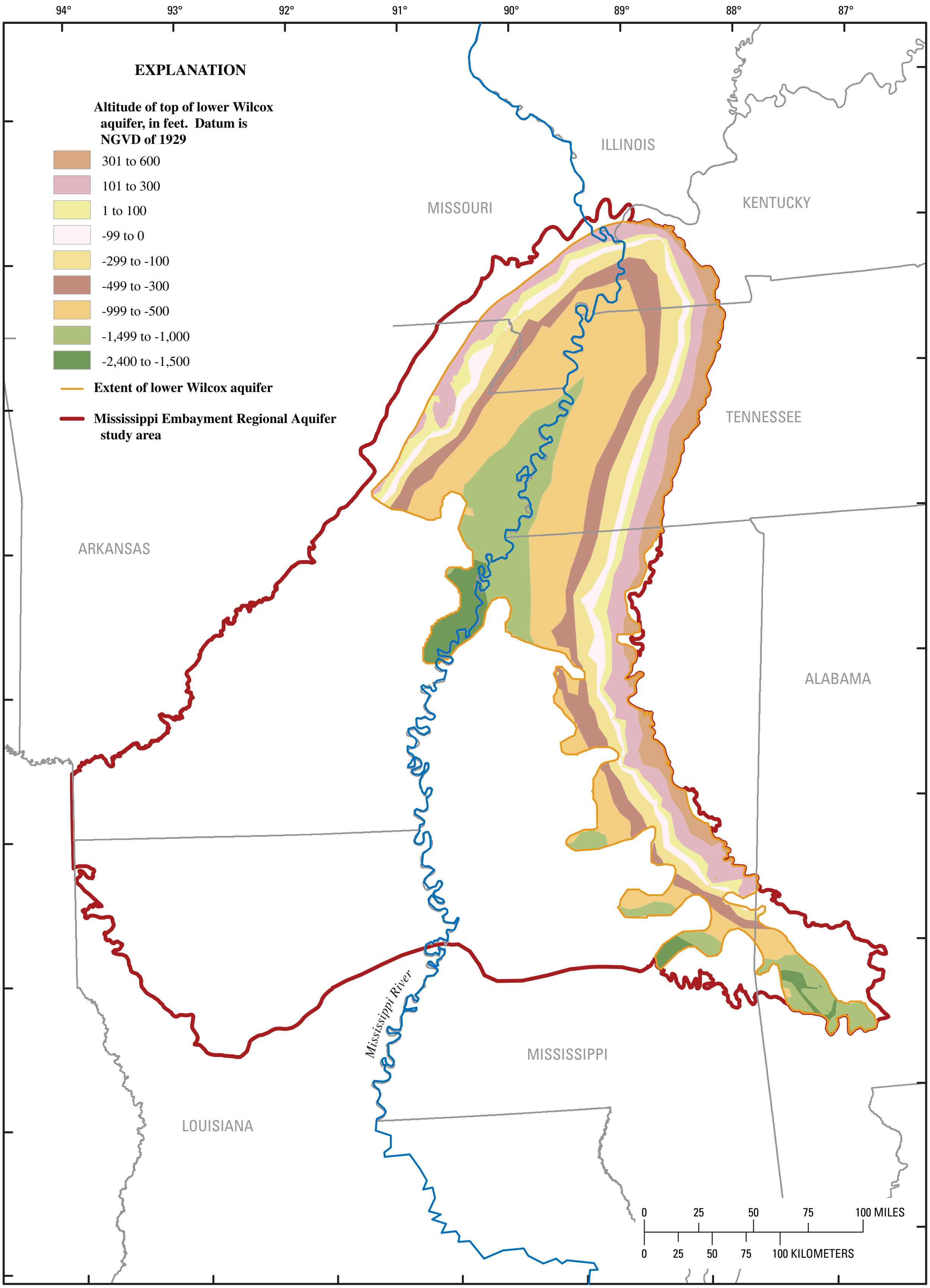

Figure 20. Altitude of top of lower Wilcox aquifer.

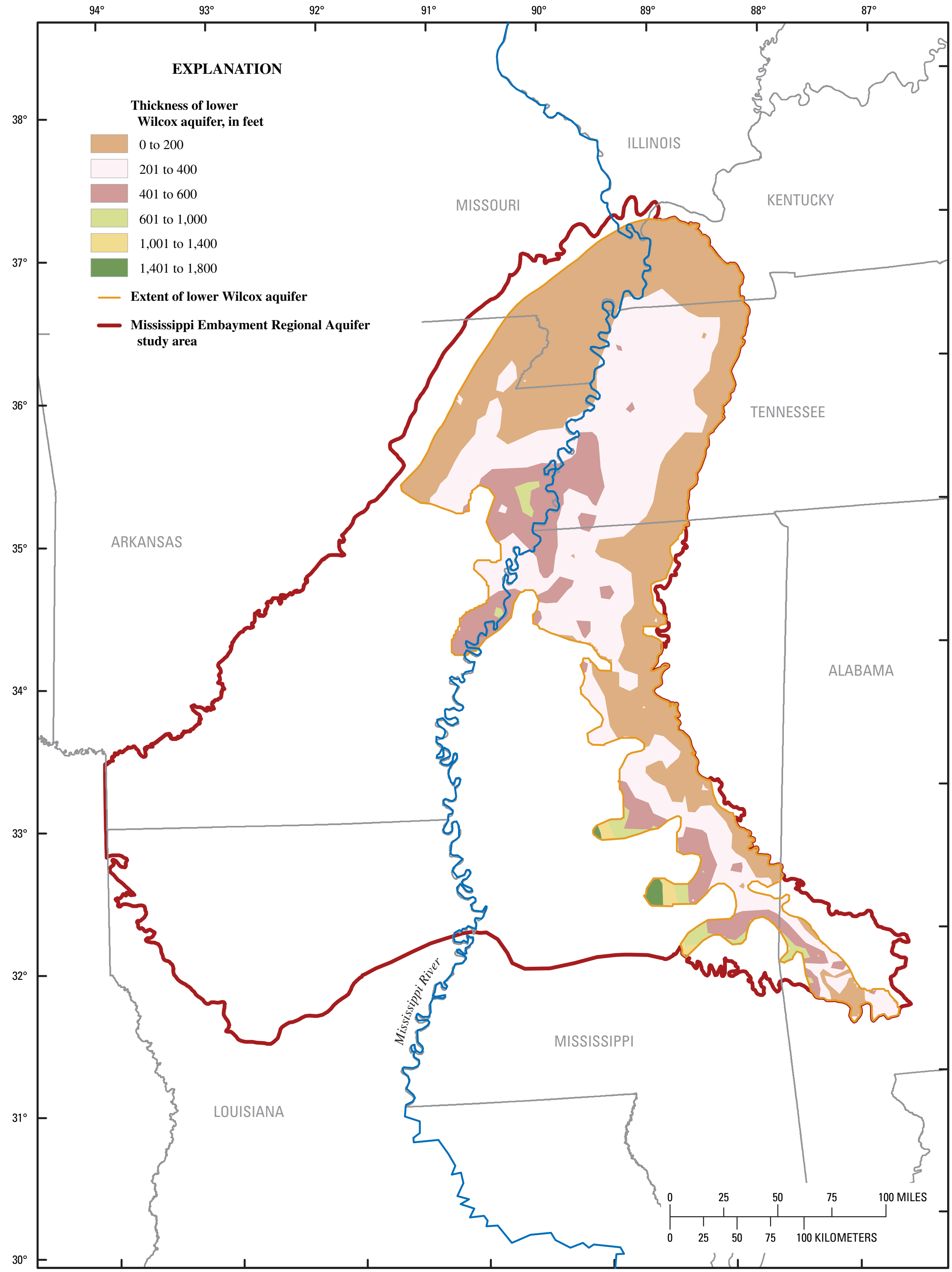

Figure 21. Thickness of lower Wilcox aquifer.

Midway Confining Unit

The Midway confining unit (fig. 4) is a thick sequence of marine clay beds that hydraulically separates the middle and lower Wilcox aquifers from the underlying aquifers of Cretaceous age. The Midway confining unit occurs throughout nearly the entire study area (fig. 22) and is composed primarily of units of the Midway Group (table 1). The highest altitudes of the interpreted top of the confining unit are located along eastern edges of the study area and can reach up to approximately 550 ft above NGVD of 1929 (fig. 22). The lowest altitudes of the interpreted top of the confining unit are approximately 6,035 ft below NGVD of 1929 and are located at the southern edge of the study area along the axis of the embayment. No hydrogeologic surfaces were constructed below the Midway confining unit for this report; therefore, the thickness of the Midway confining unit was not interpreted. This confining unit is the base of the flow system for the Tertiary aquifers discussed in this report.

Summary

Digital surfaces and thickness maps of the primary Tertiary-age hydrogeologic units in the Mississippi embayment aquifer system were created for a 70,000-mi2 study area that included parts of eight states within the Mississippi embayment. More than 2,600 normal-resistivity, spontaneous potential, and natural-gamma geophysical logs were used to create the digital surface and thickness maps for each of the hydrogeologic surfaces. The digital surface and thickness maps were created to provide a framework for a steady-state and transient ground-water flow model being developed to determine ground-water availability within the Mississippi Embayment Regional Aquifer Study (MERAS) area. The hydrogeologic surfaces were created using the interpolation method of ANUDEM through a GIS as a means for defining and displaying the hydrogeologic surfaces of the Mississippi embayment aquifer system. Thickness maps were constructed by calculating the difference between the altitude of the base of an overlying unit and the altitude of the top of an underlying unit.

The Mississippi embayment aquifer system lies within a plunging syncline with the axis primarily trending southward roughly parallel to the Mississippi River. The plunging syncline causes the beds to dip and thicken towards the axis, and most units outcrop towards the eastern and western boundaries of the Mississippi embayment. The highest interpreted hydrogeologic surface altitudes in the study area reach 650 ft above NGVD of 1929 in the outcrop areas along the eastern edge of the study area, and the lowest altitudes reach in excess of 6,035 ft below NGVD of 1929, and in general, were located along the southern edge of the study area along the axis of the embayment. The Mississippi River valley alluvial aquifer and the lower Claiborne aquifer are the thinnest aquifers of importance in the study area. The average interpreted thicknesses for each aquifer are 130 ft, and they generally range in thickness from 110 ft to 150 ft and 50 ft to 195 ft, respectively. The thickest aquifer of importance is the middle Claiborne aquifer with an average interpreted thickness of 820 ft, and generally ranges in thickness from 475 ft to 1,125 ft.

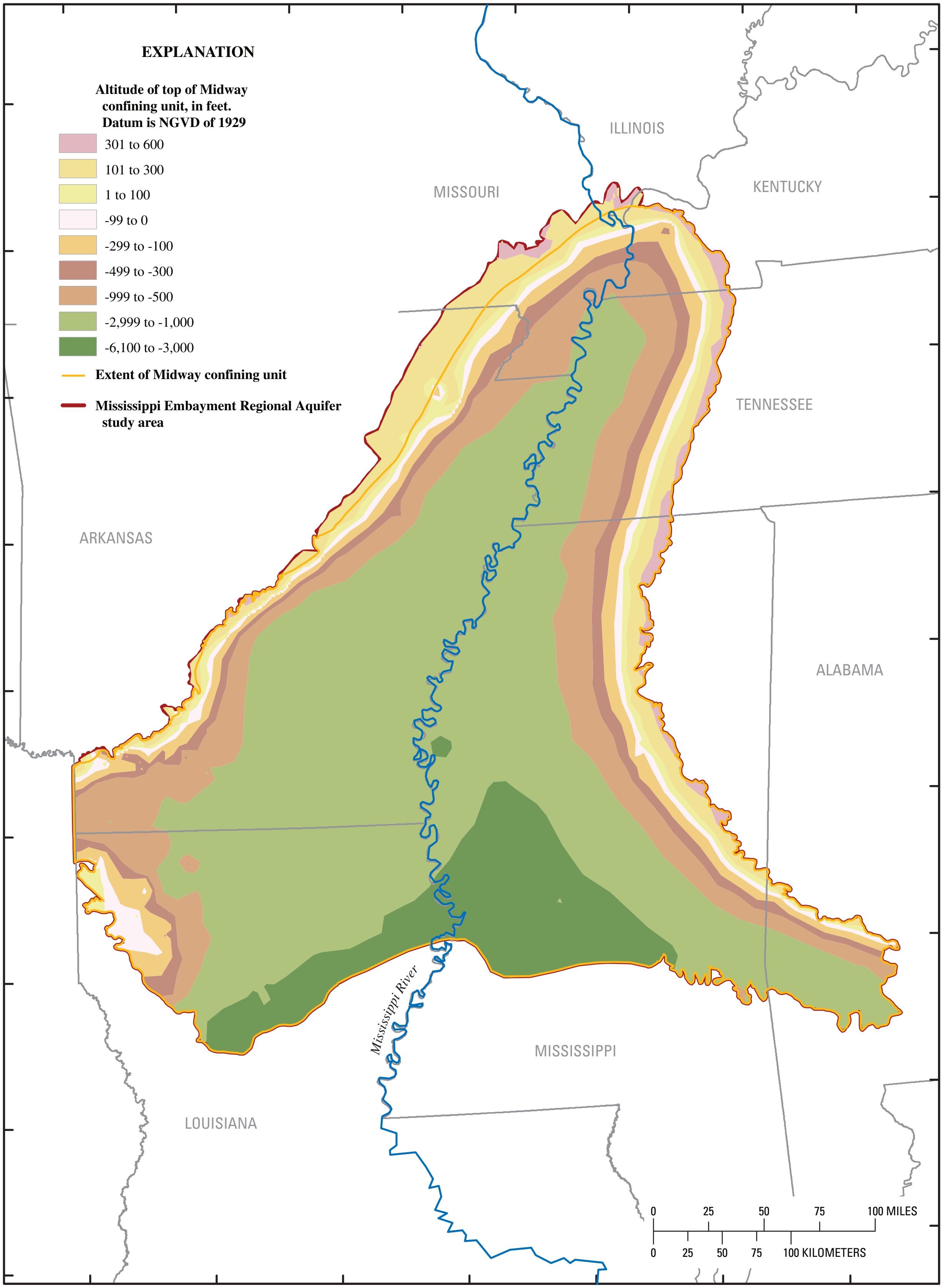

Figure 22. Altitude of top of Midway confining unit.

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