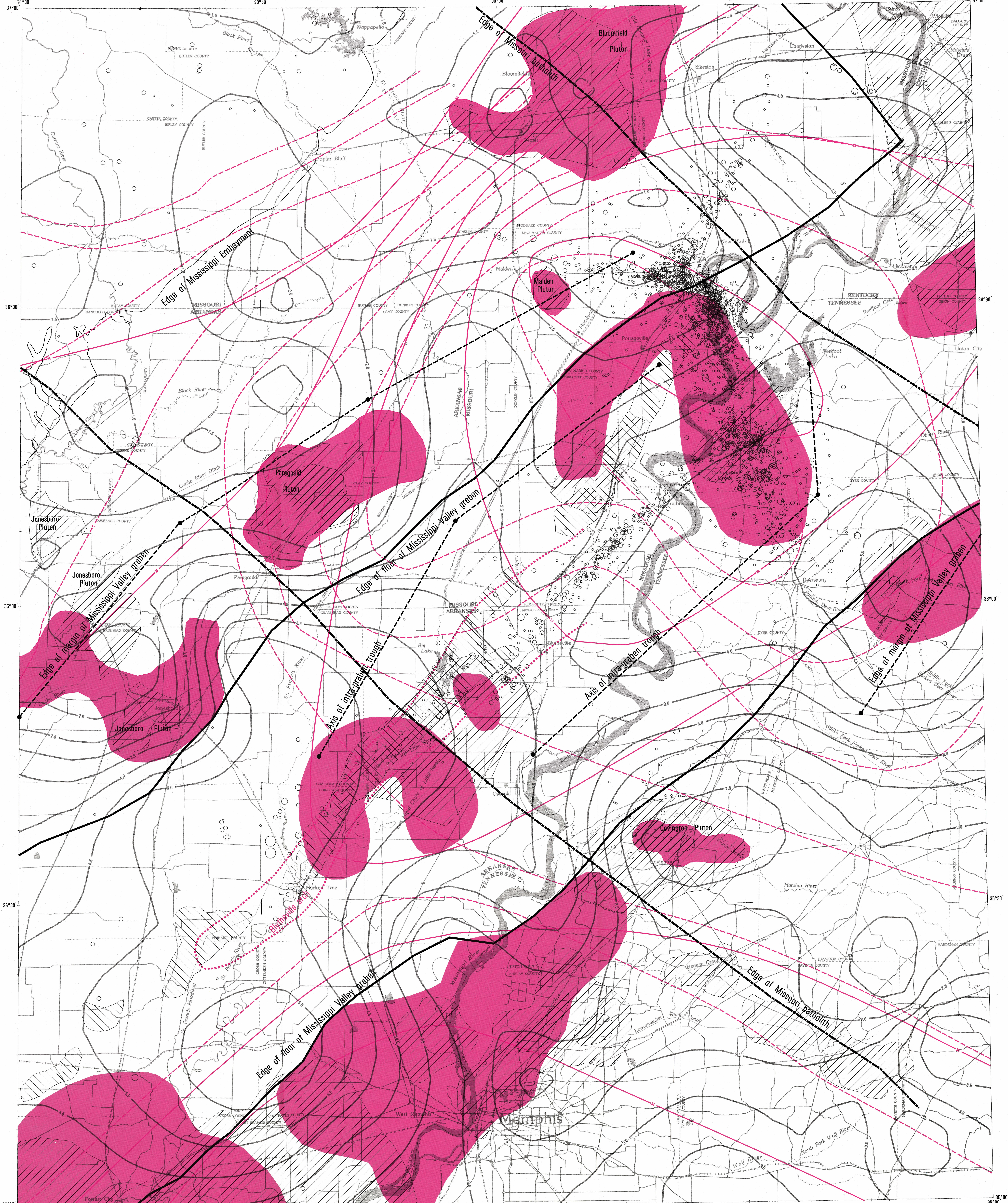

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SCALE 1:250,000

5 0 5 10 15 20 25 30 KILOMETERS

5 0 5 10 15 20 25 30 MILES

Albers Equal-Area Conic Projection
Standard Parallels 29°30′ and 45°30′

MAP SHOWING LARGE STRUCTURES INTERPRETED FROM GEOPHYSICAL DATA IN THE VICINITY OF NEW MADRID, MISSOURI

By

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1994

EXPLANATION

- Depth to magnetic basement, in kilometers below sea level
- **Structure of anomalous crust**
  - Depth, in kilometers below ground level
  - Thickness, in kilometers
- **Mafic plutons inferred from magnetic data**--Lack of outline indicates intrusive complex
- **Mafic pluton inferred from gravity data**
- **Dense core within mafic pluton**--Inferred from gravity data
- **Dense, nonmagnetic rocks aligned near center of Mississippi Valley graben**
- Structure inferred from seismic reflection data
- Structure inferred from aeromagnetic data
- Structure inferred from gravity data
- Structure inferred from magnetotelluric data
- Control point on structure inferred from magnetotelluric data
- **Earthquake epicenters, scaled by earthquake magnitude**
  - Less than 2.0
  - Between 2.0 and 2.9
  - Between 3.0 and 3.9
  - Greater than 4.0
- State boundary
- County boundary
- Selected city or town if not identified by road intersections
- Limited access, primary, or secondary road
- Railroad
- Selected river, stream, or irrigation ditch
- Wide river, selected lake or pond

DISCUSSION

This is one of a series of five seismotectonic maps of the seismically active New Madrid area in southeast Missouri and adjacent parts of Arkansas, Kentucky, and Tennessee (table 1). We cannot legibly show all the seismotectonic data on a single map, therefore each of the five maps in this series groups a different type of related information. Rhea and others (1994) summarized the background and purpose of the seismotectonic map folio.

The edge of the Mississippi embayment, as shown on the map, marks the contact between the flat-lying or gently dipping Mesozoic and Cenozoic strata of the Mississippi embayment to the southeast and the exposed Paleozoic sedimentary rocks of the midcontinent to the northwest. Most of the structures shown on this map are interpreted from analyses of gravity or aeromagnetic data (table 2); the other structures were detected with magnetotelluric or seismic methods.

We note four intriguing spatial associations on this map. The first spatial association is between the locations of abundant earthquake epicenters and anomalous lowest crust. The greatest concentration of earthquakes in the map area, and indeed in the eastern United States, forms a north-northwest-trending band of epicenters in the northeast quadrant of the map area, stretching from New Madrid, Mo. to Dyersburg, Tenn. (Stauder and others, 1976). Chiu and others (1992) showed that precisely located earthquakes in the epicentral band locate a tabular zone that strikes northwest and dips southwest between depths of 4 and 14 km. Chiu and others (1992) suggested that the Lake County uplift, a topographically high area coincident with the epicentral band, resulted from seismic uplift of the hanging wall of a southwest-dipping reverse fault. Seismic waves in the lowest crust beneath the map area have an anomalously high velocity of 7.3 km/s in a wide, domal mass that is centered under the northeast quarter of the map area (Mooney and others, 1983; Hildenbrand, 1985). These reports attributed this domal mass to injection of mantle material into the lower crust during the extensional development of the Reelfoot rift. The Mississippi Valley graben, as shown on the map, is an upper crustal expression of the Reelfoot rift (Kane and others, 1981). Hildenbrand (1985) drew isopachs and structure contours on the top surface of this anomalous domed crust and determined that within the uncertainty of his depth estimates (table 2), the two sets of contours show the anomalous crust is thickest and its top is shallowest along northwest trends at or southwest of the New Madrid-Dyersburg epicentral band. The anomalous domed crust appears to be denser and have a higher seismic velocity than surrounding lower crustal rock (Mooney and others, 1983; Hildenbrand, 1985) and therefore, it likely has a higher proportion of gabbroic or ultramafic rocks. Because gabbroic and ultramafic rocks have higher melting temperatures than common felsic rocks, the anomalous lower crust is likely to be stronger and less susceptible to deformation than surrounding crustal rocks. A strong inclusion in a weaker plate will concentrate stress within the plate near the edge of the inclusion (Campbell, 1978). Hildenbrand (1985) suggested that the domed anomalous crust could concentrate stress and ductile strain into the surrounding and overlying, more felsic, crustal rocks, thereby causing the overlying upper crust to fail seismically, presumably in the manner interpreted by Chiu and others (1992).

A second spatial association exists between the Blytheville arch and an epicentral alignment that extends southwest from Caruthersville, Mo., as noted by Crone and others (1985), Hamilton and McKeown (1988), and McKeown and others (1990). These reports suggest that seismic release of strain might be concentrated in the deformed and presumably weak rocks of the arch. Langenheim (1994) notes that the longest of five aligned masses of dense, nonmagnetic rocks also coincides with the arch and the epicentral alignment. Northeast of Blytheville, Ark., the dense rocks diverge northward from the arch and epicentral alignment.

A third spatial association is seen by contrasting the edges of plutons as inferred from gravity data to outlines as inferred from aeromagnetic data. The differences reflect compositional heterogeneity in the inferred plutons (Ravat and others, 1987; Rhea and others, 1992). Specifically, aeromagnetic anomalies reflect concentrations of magnetic minerals (mainly magnetite) that are minor or trace components of most igneous rocks. Pluton boundaries inferred from aeromagnetic data will be affected by many factors that vary horizontally and vertically in a pluton, including differences in magma compositions, oxygen fugacities, and cooling histories. In contrast, gravity anomalies reflect variations in rock density, which can also vary in a pluton. Gravity and aeromagnetic anomalies over most inferred plutons are highs in the map area, which means the plutons are mostly mafic (Hildenbrand, 1985). In contrast, some of the igneous complexes shown on the map have more subdued gravity highs than the plutons and might contain less mafic or more varied rocks (T.G. Hildenbrand, written commun., 1993).

A fourth spatial association exists between three different estimates of the edges of the Mississippi Valley graben. The graben may be thought of as consisting of a down-dropped floor, bordered by margins that slope or step downward to the floor from the shallower basement outside the graben. The first estimate of the graben edges is represented by two thick, solid, black lines marking the lateral extent of the graben floor (table 2). Hildenbrand and Hendricks (1994) note that the graben margins might have considerable widths, perhaps extending as far as 25 km outside the edges of the graben floor. However, locally the main fault zones at the margins might be only 3-9 km wide (Hildenbrand, 1982; Thomas, 1989; McKeown and others, 1990). The second estimate, represented by the map of depths to magnetic basement (fig. 1), also outlines the width of the graben, but shows it as wider than the graben floor because the magnetic-depth map reflects the graben margins as well (T.G. Hildenbrand, written commun., 1993). The third estimate represented by the dashed black lines shows the graben edges as interpreted from magnetotelluric data (table 2). The magnetotelluric interpretation of the graben is wider than the graben floor, and this interpretation, too, probably reflects the graben margins (Stanley and Rodriguez, 1992; B.D. Rodriguez and W.D. Stanley, 1993, written commun.). Thus, all three estimates of the graben width are in rough agreement.

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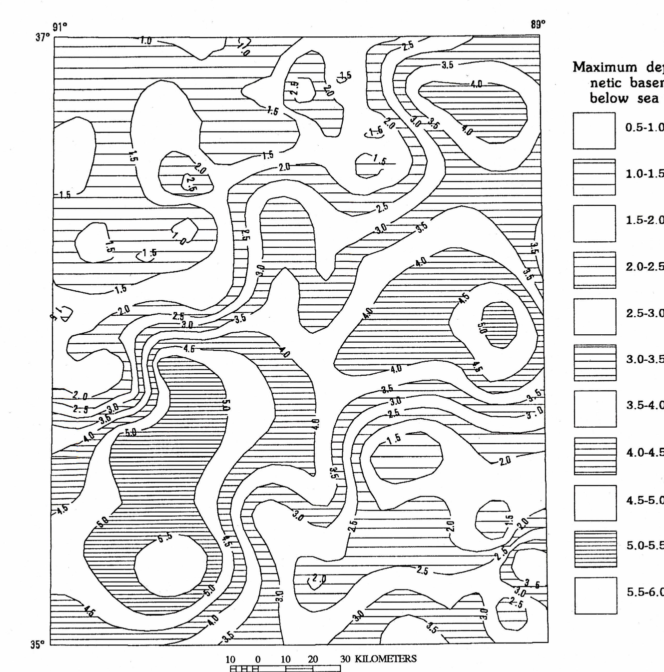

Figure 1. *Contours of maximum depth to magnetic basement, in kilometers below sea level. Contour interval 0.5 km.*

Table 1. *Maps in the U.S. Geological Survey seismotectonic folio of the New Madrid, Mo., area*

Map	Theme: features shown	Reference
MF-2264-A	Seismicity: earthquake epicenters, focal mechanisms, seismic velocities, instrument locations, and aspects of liquefaction	Rhea and others (1994)
MF-2264-B	Crustal structure: epicenters; large structures inferred from gravity, aeromagnetic, seismic reflection, seismic refraction, and magnetotelluric data	This map
MF-2264-C	Geophysical surveys: epicenters; lines of gravity, aeromagnetic, magnetotelluric, seismic reflection, and seismic refraction surveys and models	Rhea and Wheeler (1994)
MF-2264-D	Bedrock geology: epicenters; geologic and subcrop contacts; structure contours; radon concentrations; selected wells; selected faults; and arches, troughs, and faulted boundaries of the Mississippi Valley graben	Wheeler and others (1994)
MF-2264-E	Surficial and hydrologic features: epicenters; aspects of liquefaction; trench sites; earthquake-induced landslides; courses of the Mississippi River since 1765; fluvial and hydrologic anomalies; selected topographic features; Bootheel lineament; and geodetic monuments	Wheeler and Rhea (1994)

Table 2. *Large structures interpreted from geophysical data, New Madrid, Mo., area*
[Locations or outlines were digitized by cited authors unless stated otherwise. Sharp corners of some outlines are artifacts of widely spaced digitizing points]

Mapped feature	Methods, locational uncertainty, and sources
Earthquake epicenters	Located by local seismograph network, generally reported to nearest 0.01° (about 1 km) (Taylor and others, 1991; Rhea and others, 1994).
Blytheville arch	Identified from seismic-reflection profiles (Crone and others, 1985; Hamilton and McKeown, 1988; McKeown and others, 1990; McKeown and Diehl, 1994). Profiles in these reports show arch flanks as outward -dipping reflectors 2-5 km wide; gradational arch boundaries chosen in the outermost parts of the flanks.
Edges of Mississippi Valley graben floor, as inferred from aeromagnetic data	Identified from maps of maximum intensity of horizontal gradient of pseudogravity field, and of first vertical derivative of reduced-to-pole aeromagnetic field (Hildenbrand and Hendricks, 1994). Hildenbrand and Hendricks (1988) state that margins of graben might extend large distances outside these lines, and refer to more detailed studies (Hildenbrand, 1982; Crone, 1992; McKeown and others, 1990).
Structures inferred from magnetotelluric data	Inferred from the shape of a high-resistivity crustal layer that corresponds to the top of Precambrian metamorphic and igneous basement and part of the overlying basal Cambrian clastic rocks (Stanley and Rodriguez, 1992; B.D. Rodriguez and W.D. Stanley, 1993, written commun.). The inferred features include the graben edges or tops of the inward-sloping margins of the Mississippi Valley graben, a central axial high, and two intra-graben troughs that bracket the axial high. All these features trend northeast and we show the two graben edges and the two trough lines. We plotted the points where the four linear features cross as many as four east-west profiles along which Stanley and Rodriguez (1992) and B.D. Rodriguez and W.D. Stanley (1993, written commun.) calculated cross sectional models. We then connected the control points to approximate the linear features. From the spacing of the magnetotelluric stations of Stanley and Rodriguez (1992) and B.D. Rodriguez and W.D. Stanley (1993, written commun.) we estimate that the linear features are probably located on the map to within 5 km of where they cross the profiles.
Mafic plutons and intrusive complexes as outlined by aeromagnetic data	Inferred from maps of first vertical derivative of reduced-to-pole aeromagnetic field and of maximum horizontal gradient of pseudogravity field (Hildenbrand and Hendricks, 1994). Locational uncertainty varies along pluton and complex boundaries.
Mafic plutons as outlined by gravity data	Inferred from map of maximum horizontal gradients of gravity field (Langenheim, 1994; Hildenbrand and Hendricks, 1994). Langenheim also outlined dense cores within two plutons in the map area and her report's figures show two others (V.E. Langenheim, oral commun., 1993). Locational uncertainty varies along boundaries of plutons and their internal gravity highs.
Nonmagnetic, dense masses aligned near center of graben	Inferred from map of first vertical derivative of high-resolution gravity field, and map of high-resolution residual gravity field (figs. 3 and 6 of Langenheim, 1994, respectively). Locational uncertainty varies along boundaries of the five aligned, dense masses.
Depth to magnetic basement	Depths are maximums to Precambrian metamorphic and igneous rocks or to younger igneous rocks. Contoured from point depth estimates with average spacing of about 20 km in map area (Hildenbrand and Hendricks, 1994).
Edges of Missouri batholith	Inferred from maps of complete Bouguer and pseudogravity fields (Hildenbrand and Hendricks, 1994). Batholith margins might have substantial width. For example, Hildenbrand and Hendricks (1994) modeled one margin as 18 km wide. They estimate that their maps restrict possible strike-slip offset by the New Madrid seismic zone to less than 10 km.
Depth to, and thickness of, anomalous lowest crust	Values constrained by 2 1/2-dimensional modeling of gravity and aeromagnetic data (Hildenbrand, 1985) and by depths from seismic refraction studies (Mooney and others, 1983). Hildenbrand (1985) estimated that the contoured values are accurate to within 4 km vertically, if the model parameters are correct. We digitized the contours shown here from maps of Hildenbrand (1985) at scales of about 1:1,000,000 and 1:2,700,000.

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