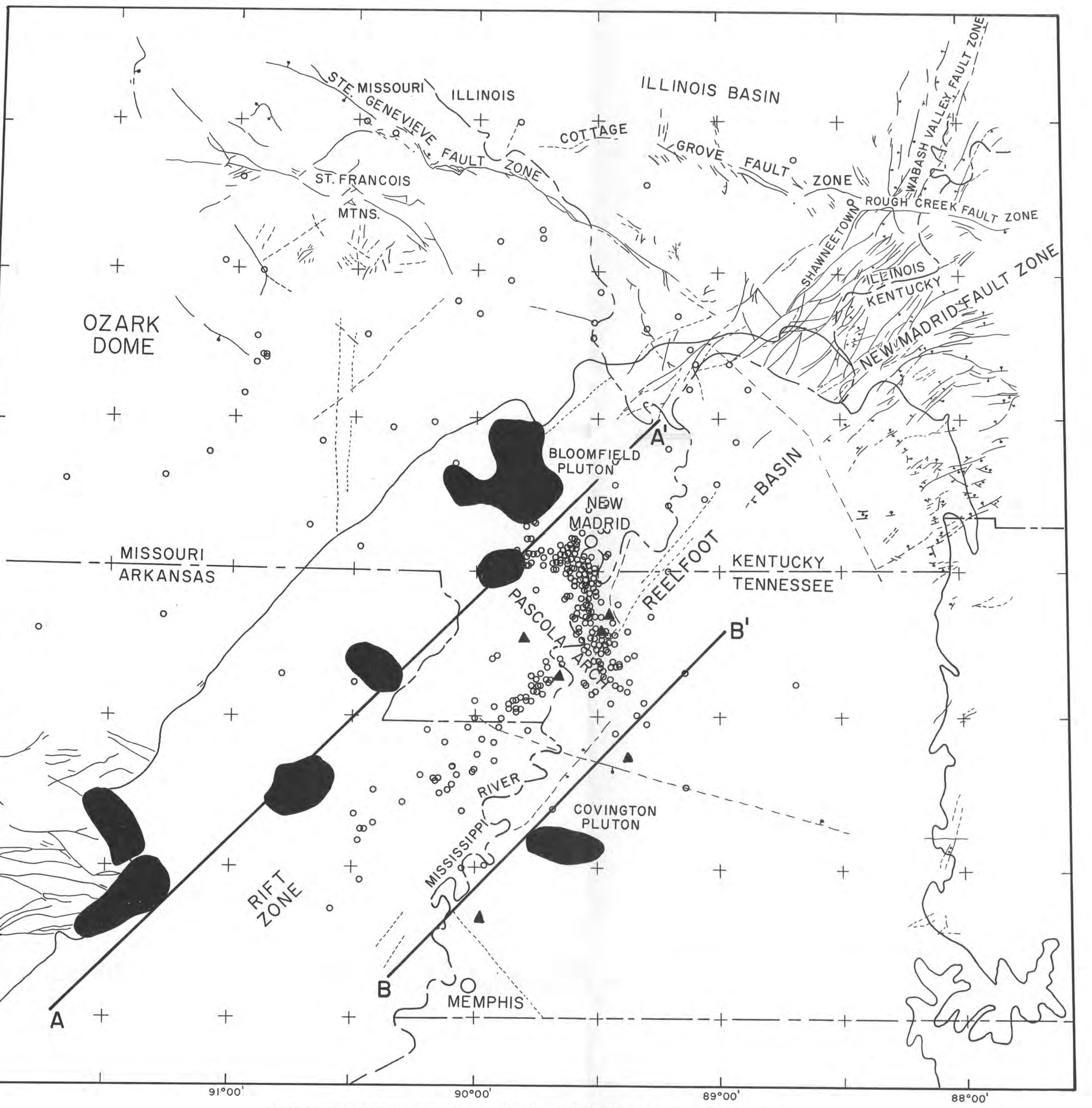

Figure 1.--Seismotectonic map of the northern Mississippi embayment and surrounding regions.

EXPLANATION

Northern limit of coastal plain material of the Mississippi embayment

Mafic or ultramafic intrusion (within the Mississippi embayment) encountered in a drill hole

Mafic or ultramafic intrusion (within the Mississippi embayment) interpreted from the magnetic and gravity fields. Approximate boundary of intrusion determined from zero contour of associated anomaly on the second vertical derivative magnetic map

Fault--Bar and ball on downthrown side. Dashed where inferred

Possible or hypothetical fault based upon subsurface data or exceptionally strong lineaments from aerial photos

A A' Approximate margins of proposed rift

Earthquake epicenter

Note: This map has been modified from the Tectonic map of the United States (Cohee and others, 1962) and the seismotectonic map of the Mississippi Valley (Heyl and McKeown, unpublished data). It is provided as a reference for the accompanying gravity and magnetic maps and it is not intended as a revision of the source mentioned. Generalization involved in enlarging the Tectonic map of the United States at a scale of 1:2,500,000 and reducing the seismotectonic map of the Mississippi Valley at a scale of 1:500,000 to the scale of 1:1,000,000 has resulted in discrepancies in some locations amounting to several kilometers.

Epicenters of earthquakes detected by the southeast Missouri regional seismic network from July 1974 to June 1976 (Stauder and others, 1976) and geophysical structures indicated in the gravity and magnetic fields have been added to this map.

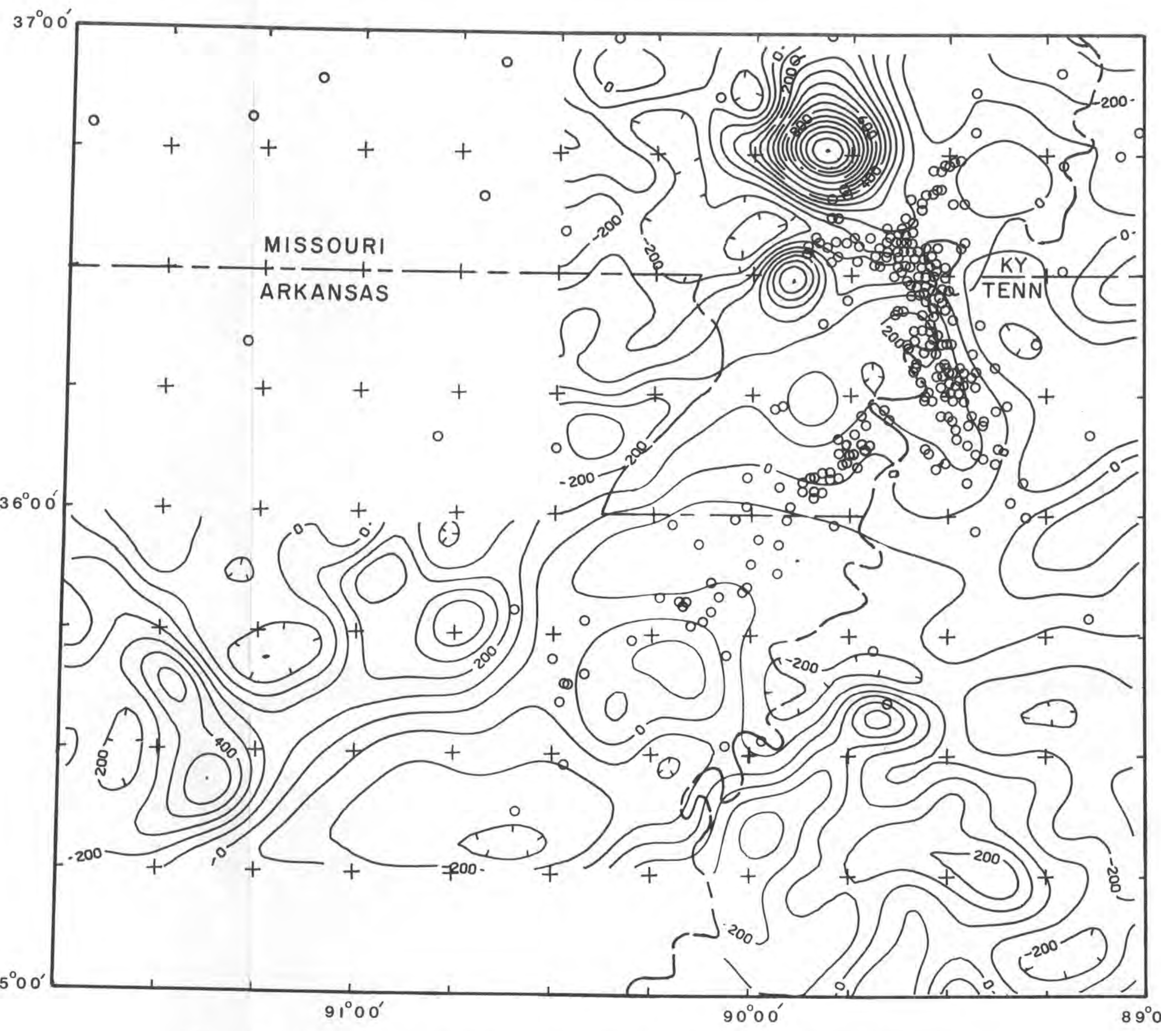

Figure 2.--Total magnetic field intensity map. Epicenters of earthquakes (detected by the southeast Missouri regional seismic network from July 1974 to June 1976) are denoted by the open circles.

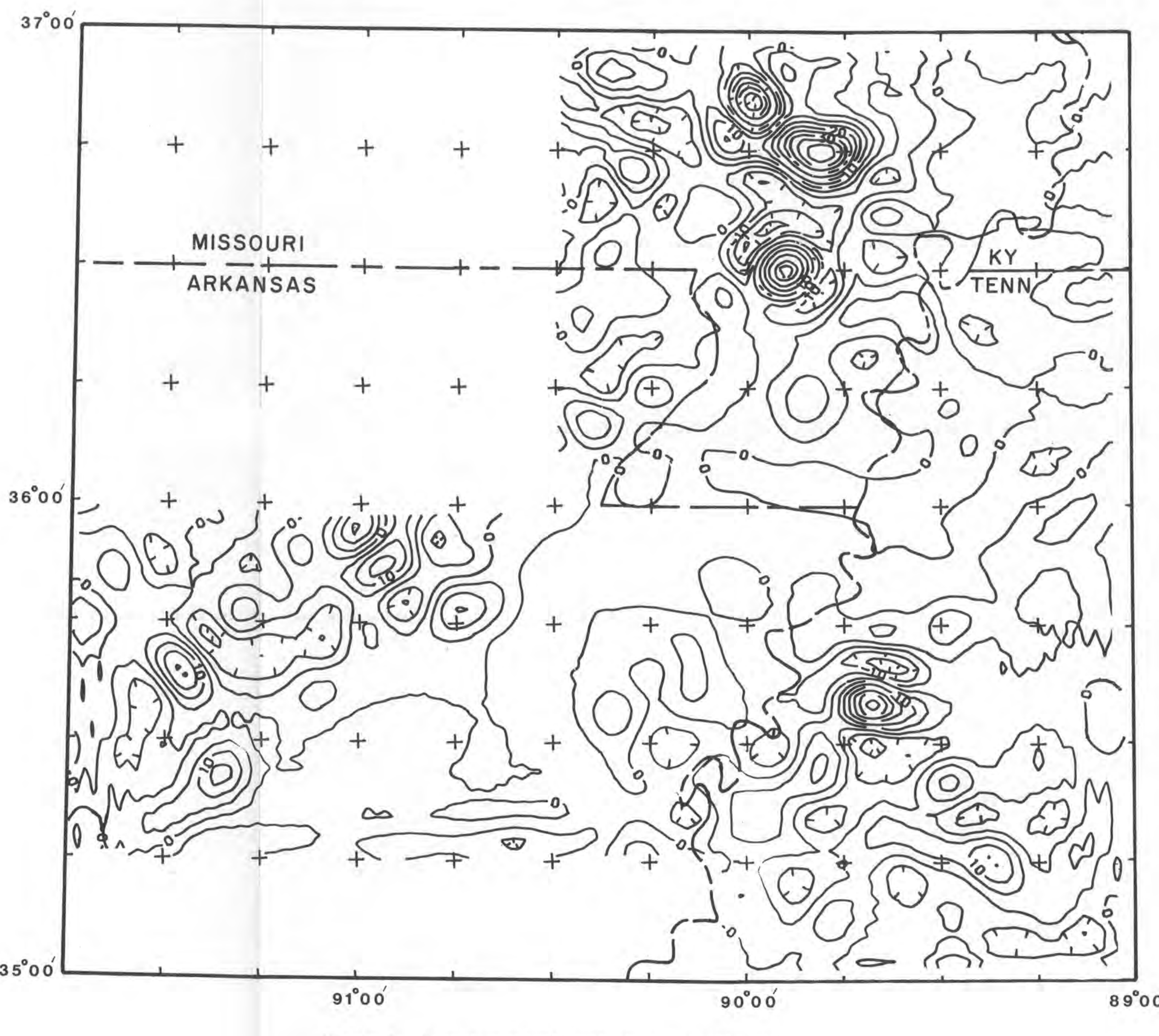

Figure 3.--Second vertical derivative magnetic map.

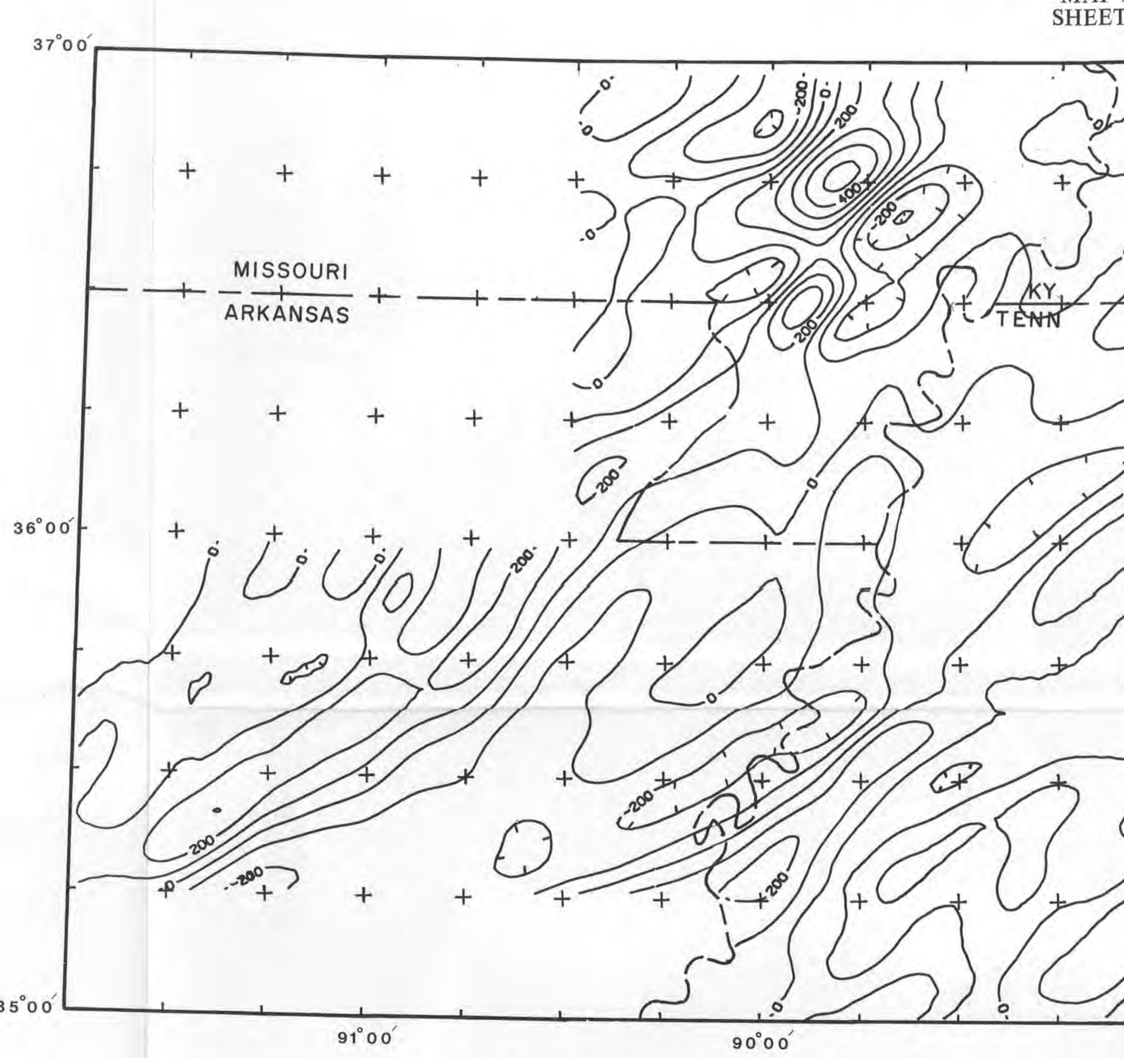

Figure 4.--North-east magnetic trend map.

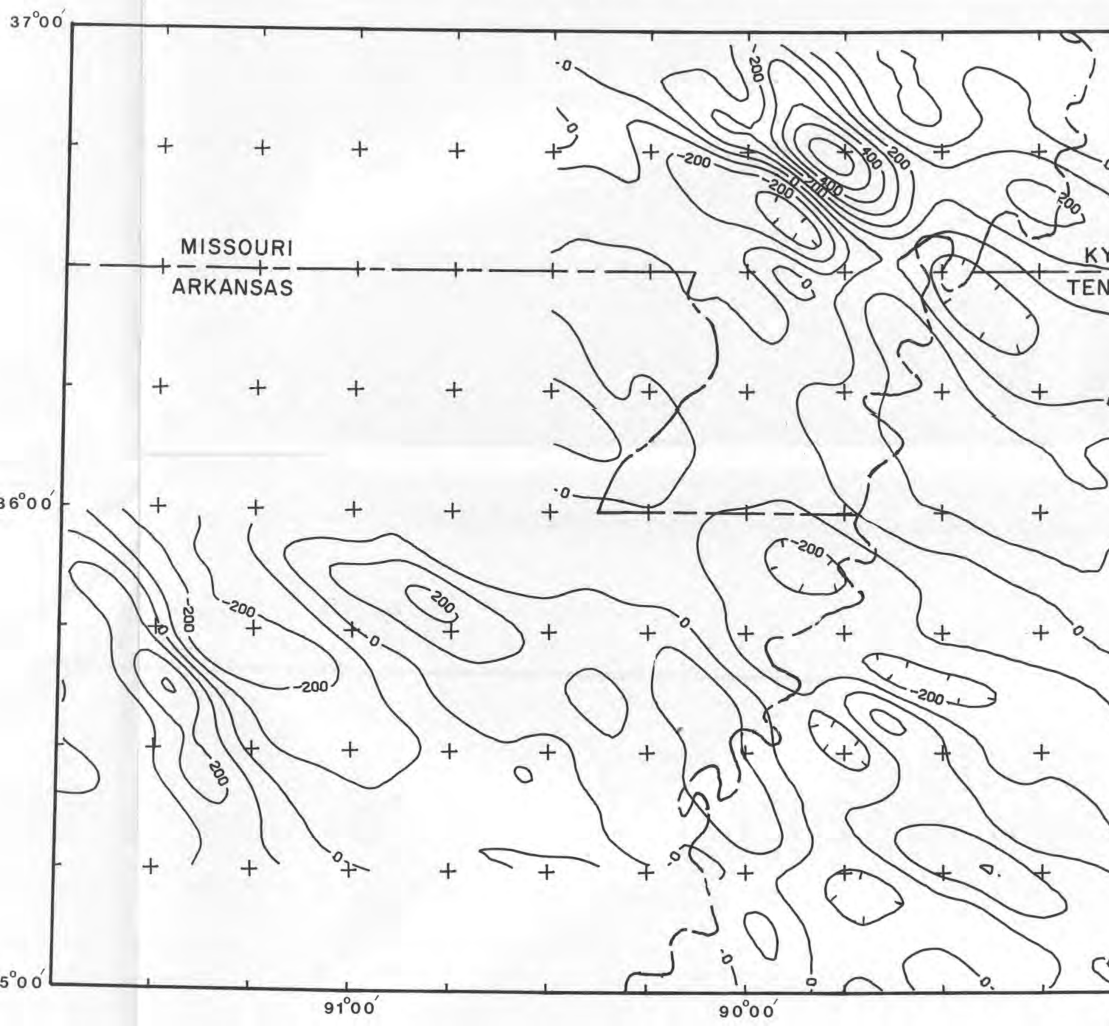

Figure 5.--North-west magnetic trend map.

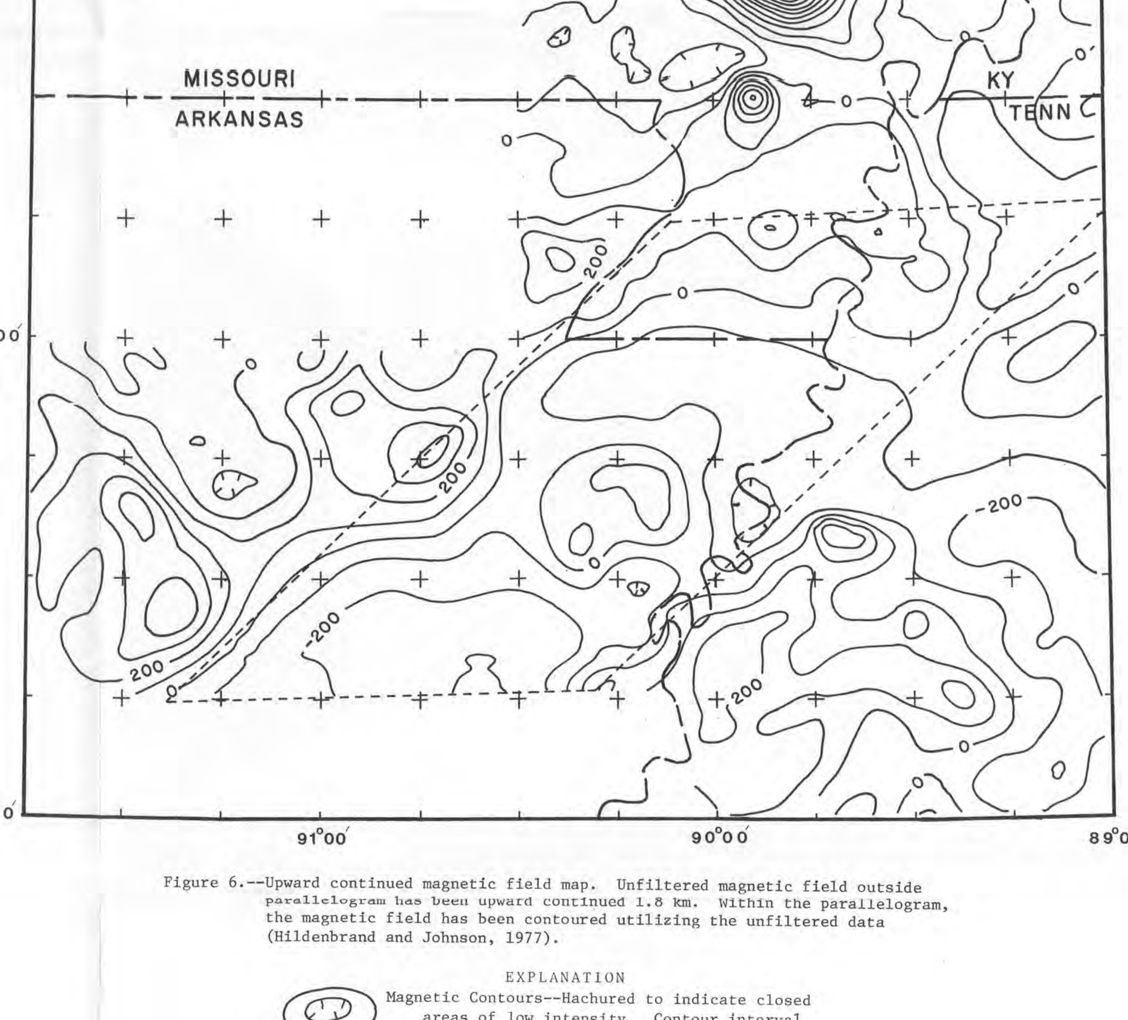

Figure 6.--Upward continued magnetic field map. Unfiltered magnetic field outside parallelogram has been upward continued 1.8 km. Within the parallelogram, the magnetic field has been contoured utilizing the unfiltered data (Hildenbrand and Johnson, 1977).

EXPLANATION

-200 Magnetic Contours--Hachured to indicate closed areas of low intensity. Contour interval is 100 gammas except in figure 3 where the interval is 5 gammas/km^2

Note: Figure 2 shows the total magnetic field intensity with the IGRF (1965 version) removed after updating to the years in which the surveys were flown (Hildenbrand and Johnson, 1977). The data contoured in figure 2 were subjected to an 8-unit Zurflueh low-pass filter (Zurflueh, 1967). The smallest wavelength transmitted by this filter is about 16 km. The mean value of the data, -354 gammas, also was removed from these contours. The aeromagnetic surveys were flown at an elevation of 0.3048 km barometric and with flight line spacings of 1.609 km (except west of 91°45' where the spacings were 0.805 km). Flight direction was east-west.

Figures 3 to 5 were obtained by subjecting the total magnetic field intensity in figure 2 to two-dimensional filtering operations. The two-dimensional discrete Fourier transform method was employed in those operations.

The northern Mississippi embayment includes an area considered to be the most seismically active region of the central United States (Algermissen, 1969). In terms of areal extent of damage, the largest earthquakes to have been recorded in North America occurred in this region and included the New Madrid earthquakes of 1811 and 1812. A modern-day reoccurrence of an equal-intensity earthquake would cause widespread loss of life and damage in central United States.

Recently, gravity and aeromagnetic surveys of the northern Mississippi embayment were conducted by the U.S. Geological Survey in order to delineate tectonic features that might explain the seismic activity. The resulting Bouguer gravity map (Hildenbrand and others, 1977a) and total magnetic field intensity map (Hildenbrand and Johnson, 1977) reveal several prominent anomalies that appear to reflect the presence of major geological or tectonic structures. These implied structures have a geometry that suggests that they may be responsible for the generation or control of seismic energy.

Map Construction

The magnetic survey was flown at an elevation of 0.305 km barometric and with flight line spacings of 1.609 km, encompassing an area of approximately 43,000 square kilometers. The total magnetic field intensity was obtained by removing the IGRF (1965 version) after updating to the years in which the surveys were flown. Nearly twenty-thousand gravity stations (Hildenbrand and others, 1977b) were collected in five states over an area of 120,000 square kilometers. The observed gravity was reduced using a Bouguer density of 2.67 gm/cc and the Geodetic Reference System 1967 formula. No terrain corrections were made because the terrain of the region is quite flat.

Both the magnetic and gravity data were digitized with a spacing of 2 km. An 8-unit Zurflueh filter (Zurflueh, 1967) was applied to the digitized data to suppress the effects of sources at the surface or at shallow depths while essentially preserving the significant deeper geological effects. The smallest wavelength transmitted by this two-dimensional filter is around 16 km. In addition, the mean values of the magnetic and gravity fields, -354 gammas and -11.4 mgals respectively, were removed from the contours of figures 2 and 7. Removing the mean has reduced Gibbs phenomena distortion (Bracewell, 1965) at the edges of those maps generated by digital filtering in the frequency domain. The resulting total-field magnetic intensity map and Bouguer gravity map are shown in figures 2 and 7, respectively.

The two-dimensional discrete Fourier transform method (Dean, 1958; Embree and others, 1963; Fuller, 1967; Naidu, 1969) was employed in order to better define anomaly trends and configurations contained in the data. Using frequency-domain filtering, north-east trends (figures 4 and 9) and north-west trends (figures 5 and 10) were emphasized on the magnetic and gravity maps. Second vertical derivative maps (figures 3 and 8) were also generated to resolve and sharpen anomalies of small areal extent. The zero contours of the second derivative map of the total magnetic field anomalies are used to outline the boundaries of causative bodies (Vacquier and others, 1951).

Seismicity of the northern Mississippi embayment is indicated in figures 1, 2, and 7. On these figures, epicenters denoted by open squares represent earthquakes detected by the southeast Missouri regional seismic network from July 1974 to June 1976 (Stauder and others, 1976). The measured displacement magnitudes range from 0.2 to 5.0. The standard error of the relative locations of the epicenters has a maximum value of 30 km but is generally less than 5 km.

As the contours in figures 2-10 were computer generated, some detail may have been lost in the compilation of these maps. Also, location of the state boundaries on these maps were taken from the seismotectonic map of the Mississippi Valley (Heyl and McKeown, unpublished data). Generalizations involved in reducing these boundaries from the seismotectonic map at a scale of 1:500,000 may have resulted in discrepancies in some locations amounting to several kilometers.

Structural Features

Figure 1 shows some major structural features in the northern Mississippi embayment and surrounding area. The features shown are modified primarily from the Tectonic map of the United States (Cohee and others, 1962) whereas fault locations have been abstracted from the seismotectonic map of the central Mississippi Valley prepared by Heyl and McKeown (unpublished data). Additional structures indicated by the present study are also included in figure 1.

In the northern Mississippi embayment post-Precambrian rocks ranging up to 6.1 km in thickness (Buschbach, written communication, 1977) overlie the Precambrian basement. Thus, the structure and geology of the Precambrian basement are known largely from the effects of Precambrian structures on younger rocks, from drill records, and from aeromagnetic and gravity surveys. In general, the buried Precambrian surface is broad and undulating. It rises on the west toward the crest of the Ozark uplift and descends deeply on the north and south beneath the Illinois basin and the Mississippi embayment, respectively. Precambrian lineaments probably are revealed by surface expressions associated with the larger regional faults (Clark and Royds, 1948; Heyl and Brock, 1961) along which displacement has been renewed throughout geologic time. A possible Precambrian fault zone which was reactivated in the Paleozoic, for example is the Rough Creek-Shawneetown-Cottage Grove fault zone (Bond and others, 1971).

On the basis of geophysical and geological data, Ervin and McGinnis (1975) suggest that the Mississippi embayment is the site of a Precambrian continental rift, the Reelfoot rift. This conclusion is compatible with earlier interpretations made by Burke and Dewey (1973) and Kumarapeli and Saull (1966), Heyl (in White, 1967, p. 382), and Burke and Dewey (1973). Subsequent erosion and tectonic activity has removed any evidence of the Reelfoot rift. However, associated axial faults may be presently active in the embayment (Caplan, 1954).

Since Precambrian time, deformation in the upper part of the Mississippi embayment appears to have been regional uplift accompanied by local subsidence. Distinctive Paleozoic features include upwarps such as the Ozark uplift and Pascola arch as well as the Reelfoot and Illinois depositional basins. Tensional forces associated with uplift and subsidence presumably led to crustal failure and mild folding. Igneous activity consisting of the emplacement of dikes, diatremes, and plugs accompanied faulting.

Ervin and McGinnis (1975) suggest that isostatic subsidence of the Reelfoot rift during early Paleozoic time produced a deep downwarp known as the Reelfoot basin. Bond and others (1971) conclude that the total Paleozoic sediment accumulation in this basin exceeded 4.25 km. In Ordovician time the Precambrian basement in southern Missouri was uplifted to form the Ozark dome, whose structural apex is the St. Francois mountains. The Illinois basin, which lies northeast of the Ozark dome, is a north-south trending spoon-shaped structure whose southern end borders the northern edge of the present study area. During Late Paleozoic time this basin was open to the south but was subsequently closed by the uplift forming the Pascola arch (Bond and others, 1971). The arch connects the Ozark uplift with the Nashville dome in central Tennessee. Tensional forces associated with the uplift of the arch may have caused faulting between the Ozark uplift and Illinois basin, producing the Ste. Genevieve fault zone on the north (Ervin and McGinnis, 1975).

The modern Mississippi embayment developed as a structural trough in Late Cretaceous and Tertiary time. Mesozoic and Cenozoic deposits more than a kilometer thick occur near Memphis, Tennessee. The axis of the embayment plunges to the south, roughly following the trend of the Mississippi River.

The present study area includes east-west trending fault zones characterized by vertical movement. The major zones are known as the Rough Creek fault zone in western Kentucky and as the Shawneetown and Cottage Grove fault zones in southern Illinois. The Shawneetown-Rough Creek fault system is a zone of sheared and faulted rock typical of a wrench-fault system (Clark and Royds, 1948). Another postulated wrench fault, the Cottage Grove, may end against the Ste. Genevieve fault zone, a well-documented high-angle thrust fault zone which has associated normal faults (Heyl and others, 1965). The Ste. Genevieve zone extends southeastward into Illinois and continues into western Kentucky as a subsurface feature.

The New Madrid fault system consists of a broad belt, approximately 80 km wide, of numerous northeastward trending narrow fault blocks and wedges. Although characterized by northeast trending faults extending southward beneath the embayment (Heyl and others, 1965), this fault system may also contain northwest-trending components (Farrar and McManamy, 1937). The fault system extends northeastward to the vicinity of the Wabash River, beyond which lies the Wabash River fault system. The New Madrid fault system is historically a zone of prominent seismicity and is the location of the New Madrid earthquake series of 1811 and 1812 (Nuttli, 1973, 1974).

Basic igneous intrusions occur near faults in this region. Fracturing associated with Ste. Genevieve fault may have accommodated the emplacement of intrusions in Early to Middle Devonian time (Zartman and others, 1967). In the Illinois-Kentucky fluorspar district kimberlite dikes and diatremes emplaced during Late Pennsylvanian and Permian are restricted to northwest trending fractures (Watson, 1967). Lamprophyres have been encountered in the Cambrian-Ordovician section on the Pascola arch (Kidwell, 1951; Grohskopf, 1955), a structure of major folding and faulting. Late Cretaceous lamprophyres, syenites, and nepheline syenites (Moody, 1949; Kidwell, 1951) have been detected in wells in southwest Tennessee. Bond and others (1971) suggest that these intrusions were emplaced along faults over a large area in southwest Tennessee paralleling the Mississippi River.

Geophysically-Inferred Structures

The total magnetic field intensity map (figure 2) and the Bouguer gravity map (figure 7) reveal several prominent anomalies that appear to reflect major geological or tectonic structures. Of particular interest is the broad zone of subdued magnetic expression that divides a region typified by higher intensities and gradients. This magnetic expression lies between longitude 90°15' and 91°30' at its southern boundary and trends approximately N.45°E. to the northeast corner of the map. The derivative map (figure 3) and the north-east trend map (figure 4) clearly display the region of low magnetic intensity and gradients. The expression of this zone is less noticeable on the gravity map due to the gravity high of large areal extent in western Tennessee that masks the gravity low associated with the zone. However, features of the gravity field related to the structure are apparent in figure 9, which emphasizes north-east gravity trends.

Using the horizontal gradient method (Vacquier and others, 1951) and the unfiltered magnetic data, average depths to magnetic basement were computed inside and outside of the zone. The results imply that the low gradients are due to 1.1-2.4 km of relief between basement inside the zone and basement outside the zone. Magnetic basement lies at an average computed depth of between 2.3 and 4.7 km below sea level. On the basis of these findings, the unfiltered magnetic data outside the zone were upward continued (Grant and West, 1965) 1.8 km to compensate for the depression of the basement. The resulting map (figure 6) reveals that the magnetic signatures within the zone remain inherently different than those outside the zone. This difference in magnetic signatures diminishes appreciably when the data outside the zone is upward continued approximately 2.4 km. Because the relief between basement inside the zone and basement outside the zone is generally much less than 2.4 km, we conclude that there must exist an intrinsic contrast in basement rock type and/or a zone of highly fractured or sheared rock. Whatever the precise cause, the zone is obviously of tectonic origin and must be intimately related to the formation of the Mississippi embayment. Because of these observations and the axial zone of seismicity (figure 1), we propose that the zone is the expression of a rift that has been active through much of geologic time since the Precambrian.

The northwest limit of the zone is denoted as line AA' on figure 1 and is characterized by a series of magnetic and gravity highs presumably caused by igneous features lying outside or along this boundary of the zone. The locations of these dense and highly magnetic intrusions are shown on the seismotectonic map (figure 1) as closed triangles denoting intrusive rocks encountered in drill holes and as closed areas with shapes representing the approximate boundaries of the intrusions. These boundaries were obtained from the zero contours of the associated anomalies on the second vertical derivative magnetic map (figure 3). The anomalies are similar to those observed over the Magnet Cove ring dike complex in Arkansas (Erickson and Blade, 1963), an alkalic igneous complex of post-Mississippian age located along the southwest projection of line AA'. A large gravity and magnetic anomaly known as the Bloomfield high (Phelan, 1969) lies near the northern end of line AA'. The Bloomfield high, which is interpreted as a buried mafic or ultramafic pluton, has a maximum gravity and magnetic amplitude of 49 mgals and 1,400 gammas, respectively. Gravity modeling of the unfiltered data indicates that the source is at a mean depth of 1.3 km below sea level and is embedded entirely within the basement complex. The calculated mean depth to the bottom of the pluton is 6.1 km below sea level. The average horizontal dimensions of the intrusion are approximately 18 km and 14 km along north-south and east-west directions, respectively. The computed model also indicates that the pluton dips to the north at an angle of 10° from the horizontal. The calculated density contrast associated with the pluton is 0.29 gm/cc. This value implies that the igneous intrusion has an intermediate or basic composition. On the southeast edge of the Bloomfield high, rock samples from a depth of 242 m in a drill hole contain cuttings with fragments that appear to be igneous (Heyl and McKeown, unpublished data). If these shallow (compared to the computed mean depth to the top of the pluton) igneous rocks represent a dike or sill injected outward from the Bloomfield pluton, then it may be of Tertiary age.

The southeast margin of the zone denoted as line BB' in figure 1 also includes magnetic and gravity highs associated with mafic or ultramafic igneous intrusions. In western Tennessee an igneous intrusion known as the Covington pluton (Phelan, 1969) has a maximum gravity and magnetic amplitude of about 41 mgals and 350 gammas, respectively. The gravity anomaly has a broad areal extent whereas the associated magnetic anomaly is more localized. The derivative gravity map (figure 8) shows that the broadness of the gravity high is due to the positive effects of secondary features in close proximity to the Covington pluton. The gravity high (and magnetic high) associated with one of these secondary features is located west and slightly north of the pluton. Although the source of this secondary feature may be a dense and highly magnetic intrusion, the low gradients of the anomaly indicate that the source lies at a greater depth than the pluton. Similar conclusions were reached for another secondary source trending southwest of the pluton and paralleling the Mississippi River. Modeling the unfiltered gravity anomaly associated with the Covington pluton indicates that this intrusion is very dense (contrast of 0.22 gm/cc) and dips gently (16°) to the south. The calculated mean depths to the top and bottom of the body are, respectively, 2.6 km and 9.4 km below sea level. The horizontal dimensions are 22 km along a north-south direction and 27 km along an east-west direction. In the vicinity of the pluton, an exploratory well encountered nepheline syenite at 0.84 km below sea level (Kidwell, 1951). The average density of nepheline syenite is 2.52 gm/cc (Thoenen and others, 1945) indicating a density contrast of -0.08 gm/cc for an assumed density of 2.6 gm/cc for the host rock. The discrepancy between the observed and computed depths (0.84 vs. 2.6 km) and density contrasts (-0.08 vs. 0.22 gm/cc) implies that only the top of the pluton is syenite. The middle and bottom sections of the intrusion must consist of denser rocks such as mafic and ultramafic masses similar to those encountered at the Pascola arch and in the fluorspar district of southern Illinois and western Kentucky.

The proposed rift is clearly defined at the southern boundary (latitude 35°) of the study area and, therefore, must extend somewhat further southwest. Northeast of the magnetic data, the projection of the zone includes a region of gravity highs presumably caused by igneous intrusions. In this region, numerous dikes and sills consisting of basic alkaline rocks, such as lamprophyre, and basic olivine-rich rocks, such as peridotite, are located along the major zones of faulting. Because of the broad areal extent of the region of gravity highs, it is suggested that these dikes and sills were injected outward from massive basic intrusions at depth. The high gravity anomalies corresponding to these deep basic intrusions may mask the older and more subdued gradients of the rift. Detailed aeromagnetic coverage in this region may better define the northern limits of the rift.

Several northwest trends observed in the potential fields (figures 5 and 10) lie nearly normal to the axis of the rift. Once such trend is a broad magnetic and gravity low geographically located over the Pascola arch. The anomaly, approximately 100 km wide, is flanked to the north and south by intense gravity and magnetic highs and extends from western Tennessee to south central Missouri. The associated source may be anomalously low-density and low-susceptibility basement rocks similar to the siliceous rocks (Phelan, 1969) outcropping nearby in the St. Francois mountains. Another northwest gravity trend (figure 7 and 10) follows the St. Genevieve fault including its buried extension in southern Illinois and western Kentucky. The associated sources of the remaining northwest trending anomalies have yet to be determined but may be related in some way (e.g., transform faults) to the presence of the rift.

Structures Spatially Related to Seismicity

The seismicity pattern in the Mississippi embayment (figure 1) suggests the existence of linear seismically active zones corresponding to active faults (Stauder and others, 1976). Major seismicity occurs between the Bloomfield pluton and the Covington pluton. Earthquakes are noticeably concentrated along the southeast edge of the Bloomfield anomaly (figure 2 and 7) possibly indicating that the corresponding pluton influences the distribution of stress in this region. Kane (1977) observes that extensive gravity highs and associated magnetic anomalies are present in or near seven major eastern North American earthquake areas as defined by Hadley and Devine (1974). The precise nature of the relationship between igneous intrusions and faulting requires closer examination.

A linear trend of epicenters striking southwest along the axis of the proposed rift suggests that the rift is presently active. The axial seismicity pattern of known spreading rifts (Sykes, 1967) is very similar to that of the rift. Another explanation for the axial seismicity may be that past rifting activity resulted in highly fractured and folded crustal material along the axis of the rift. This axis, therefore, may have represented a zone of crustal weakness along which strain produced by present-day tectonic forces is being relieved. An alternative explanation resulting from the applications of remote sensing by O'Leary and Simpson (1977) suggests that the tectonic evolution of this region is one of an episodically opening wedge. Whatever the precise cause, the axial seismicity pattern implies that further investigations pertaining to the possible dynamics of continental rifting in the embayment are warranted.

Seismicity trends change from northeast to slightly west of north at the intersection of rift zone with the Pascola arch. Strain associated with the spreading rift and/or other tectonic forces may be relieved by movement along the juncture of these two basement lineaments.

Northeast of the rift zone, events generally are located near the edges of gravity anomalies or between them (figure 7). This suggests that Precambrian basement is comprised of plutons or lithospheric blocks with faulted regions around their peripheries. Differential movements of these blocks may occur as a result of adjustments in isostatic equilibrium. McGinnis and Ervin (1974) propose that block tectonics similarly controls seismicity in the Illinois basin. Earthquake locations are very sparse east of the rift zone. The seismicity of this region may represent small adjustments to the presently active tectonic forces on the west side of the embayment.

References

Algermissen, S. T., 1969, Seismic risk studies in the United States: Proc. World Conf. Earthquake Eng., 4th, Santiago, Chile, p. 14-27.
Bond, D. C. and others, 1971, Possible future petroleum potential of region 9 - Illinois Basin, Cincinatti arch, and northern Mississippi embayment: Am. Assoc. Petroleum Geologists Mem. 15, v. 2, p. 1165-1218.
Bracewell, Ron, 1965, The Fourier transform and its applications: New York, McGraw-Hill Book Co., 381 p.
Burke, K. and Dewey, J. F., 1973, Plume-generated triple junctions: Key indicators in applying tectonics to old rocks: Jour. Geology, v. 81, p. 406-433
Caplan, W. M., 1954, Subsurface geology and related oil and gas possibilities of northeastern Arkansas: Arkansas Resources and Development Comm., Div. Geology Bull. 20, 124 p.
Clark, S. K., and Royds, J. S., 1948, Structural trends and fault systems in Eastern Interior Basin: Am. Assoc. Petroleum Geologists Bull., v 32, p. 1728-1749.
Cohee, G. V., and others, 1962, Tectonic map of the United States: U.S. Geol. Survey and Am. Assoc. Petroleum Geologists, scale 1:2,500,000.
Dean, W. C., 1958, Frequency analysis for gravity and magnetic interpretation: Geophysics, v. 23, p. 97-127.
Embree, P., Burg, J. P., and Backus, M. M., 1963, Wide-band velocity filtering-the pieslice process: Geophysics, v. 28, no. 6, p. 948-976.
Erickson, R.L., and Blade, L. V., 1963, Geochemistry and petrology of the alkalic igneous complex at Magnet Cove, Arkansas: U.S. Geol. Survey Prof. Paper 425, 95 p.
Ervin, C. P., and McGinnis, L. D., 1975, Reelfoot rift: Reactivated precursor to the Mississippi embayment: Geol. Survey of America Bull., v 86, p. 1287-1295.
Farrar, Willard, and McManamy, Lyle, 1937, The geology of the Stoddard County, Missouri: Missouri Geol. Survey, 59th Bienn. Rept., 1935-1936, App. 6, 92 p.
Fuller, B. D., 1967, Two-dimensional frequency analysis and design of grid operators: Mining Geophysics, v. 2, p 658-708.
Grant, F. S., and West, G. F., 1965, Interpretation theory in applied geophysics: New York, McGraw-Hill Book Co., 583 p.
Grohskopf, J. G., 1955, Subsurface geology of the Mississippi embayment of southeast Missouri: Missouri Div. Geol. Survey and Water Resources, v. 37, 2nd ser., 133 p.
Hadley, J. B., and Devine, J. F., 1974, Seismotectonic map of the eastern United States: U.S. Geol. Survey Misc. Field Studies Map MF-620.
Heyl, A. V., Jr., and Brock, M. R., 1961, Structural framework of the Illinois-Kentucky mining district and its relation to mineral deposits: U.S. Geol. Survey Prof. Paper 424-D, p. D3-D6.
Heyl, A. V., Jr., Brock, M. R., Jolly, J. L., and Wells, C. E., 1965, Regional structure of the southeast Missouri and Illinois-Kentucky mineral districts: U.S. Geol. Survey Bull. 1202-B, p. B1-B20.
Hildenbrand, T. G., Ervin, C. P., Hendricks, John, Keller, G. R., McGinnis, L. D., and Stearns, R. G., 1977a, Bouguer gravity map of the northern Mississippi embayment, parts of Missouri, Arkansas, Tennessee, Kentucky, and Illinois: U.S. Geological Survey, Open-File Rept. 77-228.
______, 1977b, Gravity station locations of the northern Mississippi embayment, parts of Missouri, Arkansas, Tennessee, Kentucky, and Illinois: U.S. Geological Survey, Open-File Rept. 77-230.
Hildenbrand, T. G., and Johnson, R. W., 1977, Aeromagnetic map of the northern Mississippi embayment: U.S. Geological Survey, Open-File Rept. 77-229.
Kane, M. F., 1977, Correlation of major eastern earthquake centers with mafic/ultramafic basement masses, U.S. Geological Survey Open-File Rept. 77-134.
Kidwell, A. L., 1951, Mesozoic igneous activity in the northern Gulf Coast Plain: Gulf Coast Assoc. Geol. Socs. Trans., 1st Ann. Mtg., p. 182-199.
Kumarapeli, P. S., and Saull, V. A., 1966, The St. Lawrence valley system - - A North American equivalent of the East African rift system: Canadian Jour. Earth Sci., v. 3, p. 639-658.
McGinnis, L. D., and C. P. Ervin, 1974, Earthquakes and block tectonics in the Illinois Basin, Geology, v. 2, p. 517-519.
Moody, C. L., 1949, Mesozoic igneous rocks of the northern Gulf Coastal Plain: Am. Assoc. Petroleum Geologists Bull., v. 33, p. 1410-1428.
Naidu, P. S., 1969, Estimation of spectrum and cross-spectrum of aeromagnetic field using fast Fourier transform techniques: Geophys. Prosp., v. 17, p. 344-361.
Nuttli, O. W., 1973, The Mississippi valley earthquakes of 1811 and 1812: intensities, ground motion and magnitudes: Bull. Seism. Soc. Am., v. 63, no. 1, p. 227-248.
______, 1974, Magnitude-recurrence relation for central Mississippi valley earthquakes: Bull. Seism. Soc. Am., v. 64, no. 4, p. 1189-1207.
O'Leary, D. W. and Simpson, S. L., 1977, Remote sensor applications to tectonism and seismicity in the northern part of the Mississippi embayment, Geophysics, v. 42, p. 542-548.
Phelan, M., 1969, Crustal structure in the central Mississippi valley (Ph.D. dissert.): St. Louis, Washington Univ., 166 p.
Stauder, W., Kramer, M., Fischer, G., Schaeffer, S., and Morrissey, S. T., 1976, Seismic characteristics of southeast Missouri as indicated by a regional telemetered microearthquake array: Bull. Seism. Soc. Am., v. 66, no. 6, p. 1953-1964.
Sykes, L. R., 1967, Mechanism of earthquakes and nature of faulting on the mid-oceanic ridges: Jour. Geophys. Research, v. 72, no. 8, p. 2131-2153.
Thoenen, J. R., Malamphy, M. C., and Vallely, J. L., 1945, Geophysical survey of Arkansas bauxite region: U.S. Bur. Mines Rept. Inv. 3791, 49 p.
Vacquier, V., Steenland, N. C., Henderson, R. G., and Zietz, Isidore, 1951, Interpretation of aeromagnetic maps: Geol. Society America Mem., no. 47, 151 p.
Watson, K. D., 1967, Kimberlites of eastern North America, in Wyllie, P. J., ed., Ultramafic and related rocks: New York, John Wiley & Sons, Inc., p. 312-323.
White, D. E., 1967, Outline of thermal and mineral waters as related to origin of Mississippi Valley ore deposits, with discussion, in Brown, J. S., ed., Genesis of stratiform lead-zinc-barite-fluorite deposits (Mississippi Valley type deposits)-A symposium, New York, 1966: Econ. Geology Mon. 3, p 382.
Zartman, R.E., Brock, M.R., Heyl, A. V., and Thomas, H. H., 1967, K-Ar and Rb-Sr ages of some alkalic intrusive rocks from the central and eastern United States: Am. Jour. Sci., v. 265, p. 848-870.
Zurflueh, E. G., 1967, Applications of two-dimensional linear wavelength filtering: Geophysics, v. 32, no. 6, p. 1015-1035.

SCALE 1:1 000 000

25 0 25 50 75 100 MILES

25 0 25 50 75 100 KILOMETERS

MAGNETIC AND GRAVITY ANOMALIES IN THE NORTHERN MISSISSIPPI EMBAYMENT AND THEIR SPACIAL RELATION TO SEISMICITY

By
T. G. Hildenbrand, M. F. Kane, and W. Stauder, S. J.
1977

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1977

For sale by Branch of Distribution, U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225