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CRUSTAL STRUCTURE OF THE NORTHERN MISSISSIPPI EMBAYMENT AND A COMPARISON WITH OTHER CONTINENTAL RIFT ZONES

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ABSTRACT

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Previous geological and geophysical investigations have suggested that the Mississippi Embayment is the site of a Late Precambrian continental rift that was reactivated in the Mesozoic. New information on the deep structure of the northern Mississippi Embayment, gained through an extensive seismic refraction survey, supports a rifting hypothesis. The data indicate that the crust of the Mississippi Embayment may be characterized by six primary layers that correspond geologically to unconsolidated Mesozoic and Tertiary sediments (1.8 km/s), Paleozoic carbonate and clastic sedimentary rocks (5.9 km/s), a low-velocity layer of Early Paleozoic sediments (4.9 km/s), crystalline upper crust (6.2 km/s), lower crust (6.6 km/s), modified lower crust (7.3 km/s), and mantle. Average crustal thickness is approximately 41 km.

The presence and configuration of the low-velocity layer provide new evidence for rifting in the Mississippi Embayment. The layer lies within the northeast-trending upper-crustal graben reported by Kane et al. (1981), and probably represents marine shales deposited in the graben after rifting.

The confirmation and delineation of a 7.3 km/s layer, identified in previous studies, implies that the lower crust has been altered by injection of mantle material. Our results indicate that this layer reaches a maximum thickness in the north-central Embayment and thins gradually to the southeast and northwest, and more rapidly to the southwest along the axis of the graben. The apparent doming of the 7.3 km/s layer in the north-central Embayment suggests that rifting may be the result of a triple junction located in the Reelfoot Basin area.

The crustal structure of the Mississippi Embayment is compared to other continental rifts: the Rhinegraben, Limagnegraben, Rio Grande Rift, Gregory Rift, and the Salton Trough. This comparison suggests that alteration of the lower crust is a ubiquitous feature of continental rifts.

INTRODUCTION

Geological and geophysical investigations strongly suggest that the Mississippi Embayment is the site of a Late Precambrian continental rift that was reactivated in

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the Mesozoic (Burke and Dewey, 1973; Ervin and McGinnis, 1975; Kane et al., 1981). The most direct evidence for a rift is gravity and aeromagnetic data indicating a northeast-trending graben in the upper crust of the Embayment that is presumably the result of an initial rifting phase (Hildenbrand et al., 1977; Kane et al., 1981). The graben is 70 km wide, more than 300 km long, and has a basement offset of more than 2 km. Further evidence for a rift is the occurrence of mafic alkalic plutons along the boundaries of the graben which are commonly, though not uniquely, associated with rifts (Burke and Dewey, 1973). Reflection profiles suggest several episodes of faulting and intrusive activity within the graben (Zoback et al., 1980).

Deep crustal structure studies provide additional evidence for rifting. Seismic refraction profiles west of the Embayment show that an anomalous high-velocity layer is present at the base of the crust (McCamy and Meyer, 1966; Stewart, 1968). Velocity models of the Embayment based on travel times for local earthquakes (Mitchell and Hashim, 1977) and Rayleigh wave dispersion (Austin and Keller, 1982) also include an anomalous high-velocity basal crust. Analyses of the regional gravity data by Ervin and McGinnis (1975) and Cordell (1977) suggest that the anomalous high-velocity layer thickens beneath the Embayment and forms a "fossil rift cushion". In their model, rifting is the result of epeirogenic uplift due to the emplacement of mantle material at the base of the crust.

In this paper we present the results of an extensive refraction survey of the northern Mississippi Embayment. These results, combined with gravity data, considerably expand the available information on the deep crustal structure of the Embayment. We compare the Mississippi Embayment to the Salton Trough, Gregory Rift, Limagnegraben, Rhinegraben and Rio Grande Rift to clarify similiarities in the deep structure of continental rifts.

REGIONAL SETTING

The Mississippi Embayment is a broad elongate re-entrant of the Gulf Coastal Plain that extends into the North American craton from the south. It is a south-plunging structural trough filled with unconsolidated sediments of Cenozoic and Late Cretaceous age unconformably overlying carbonate and clastic rocks of Paleozoic age. Regional structures surrounding the Embayment include the Illinois basin to the north, the Ozark uplift to the northwest, and the Nashville dome and Cincinnati arch to the northeast (Fig. 1). The Appalachian fold belt is exposed to the east, and the Ouachita tectonic belt is exposed on the southwestern flank.

The New Madrid Seismic Zone in the northern Mississippi Embayment is currently the most seismically active area in the central and eastern United States (Hadley and Devine, 1974). The three great earthquakes of 1811 and 1812 were the largest events to occur in the eastern U.S. in historical times (Nuttli, 1973). Contemporary microearthquakes define linear epicentral trends in the northern Embayment. McKeown (1978) suggests that some of the epicentral patterns are

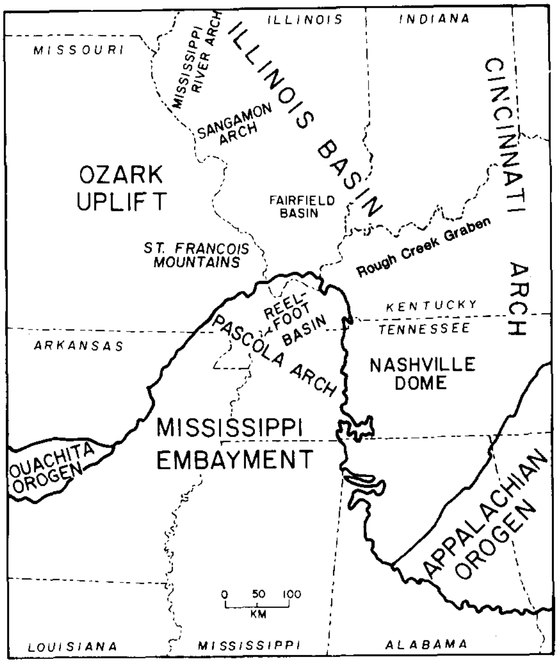


Fig. 1. The Mississippi Embayment and surrounding regional geologic features. The study area includes the Pascola Arch and the region 200 km to the south (Fig. 2).

related to stress concentrations associated with mafic alkalic plutons. Recently, a system of northeast-trending faults coincident with the main earthquake trends has been identified (Zoback et al., 1980).

REFRACTION DATA

In September 1980, the U.S. Geological Survey recorded reversed seismic refraction profiles in the northern Mississippi Embayment. A total of 34 shots were fired at nine shot points to provide axial, cross, and flank profiles (Fig. 2). Shot point locations are listed in Table I. Seismic data were recorded on FM analog tape by 100 portable seismographs (Healy et al., 1982). Seismic energy sources were 900–1800 kg chemical charges. Data were digitized and plotted in the field to assess data quality. Final record sections were filtered 2–10 Hz and plotted in normalized and true-amplitude format.

The first step of analysis was the derivation of preliminary crustal models based on measured apparent velocities and intercept times. Two-dimensional ray tracing (Cerveny et al., 1977) to obtain more precise models was followed by the computation of synthetic seismograms using the method of McMechan and Mooney (1980) to test the seismic energy distribution of the models against the observed true-amplitude data.

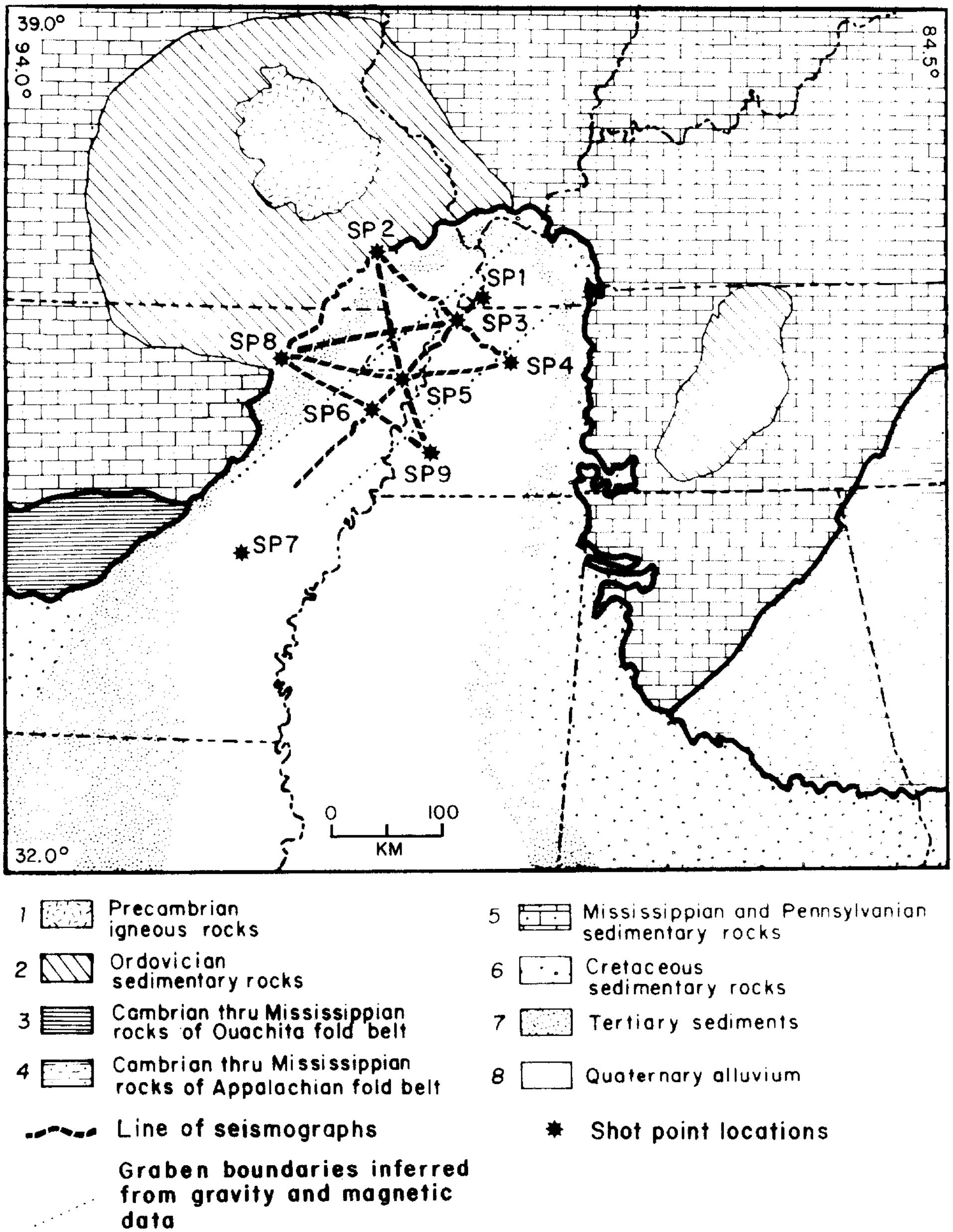


Fig. 2. Generalized geologic map of the Mississippi Embayment showing the locations of the shot points and the seismic refraction profiles. Profiles are referred to in the text by the shot points they connect, e.g., profile 8-3. The dotted lines indicate the location of the upper crustal graben as inferred from gravity and aeromagnetic data (Kane et al., 1981; Hildenbrand et al., 1977).

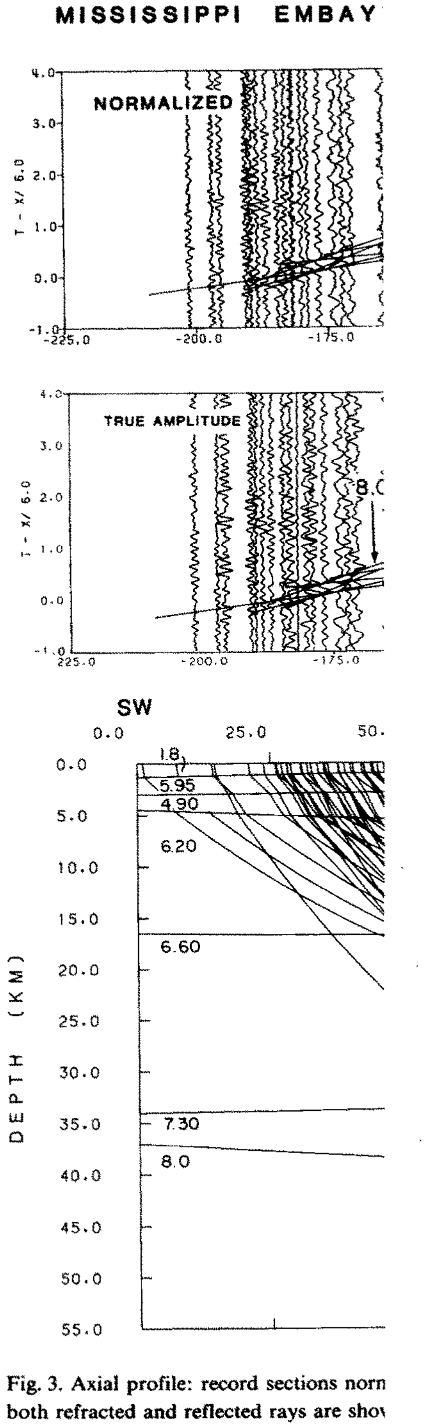
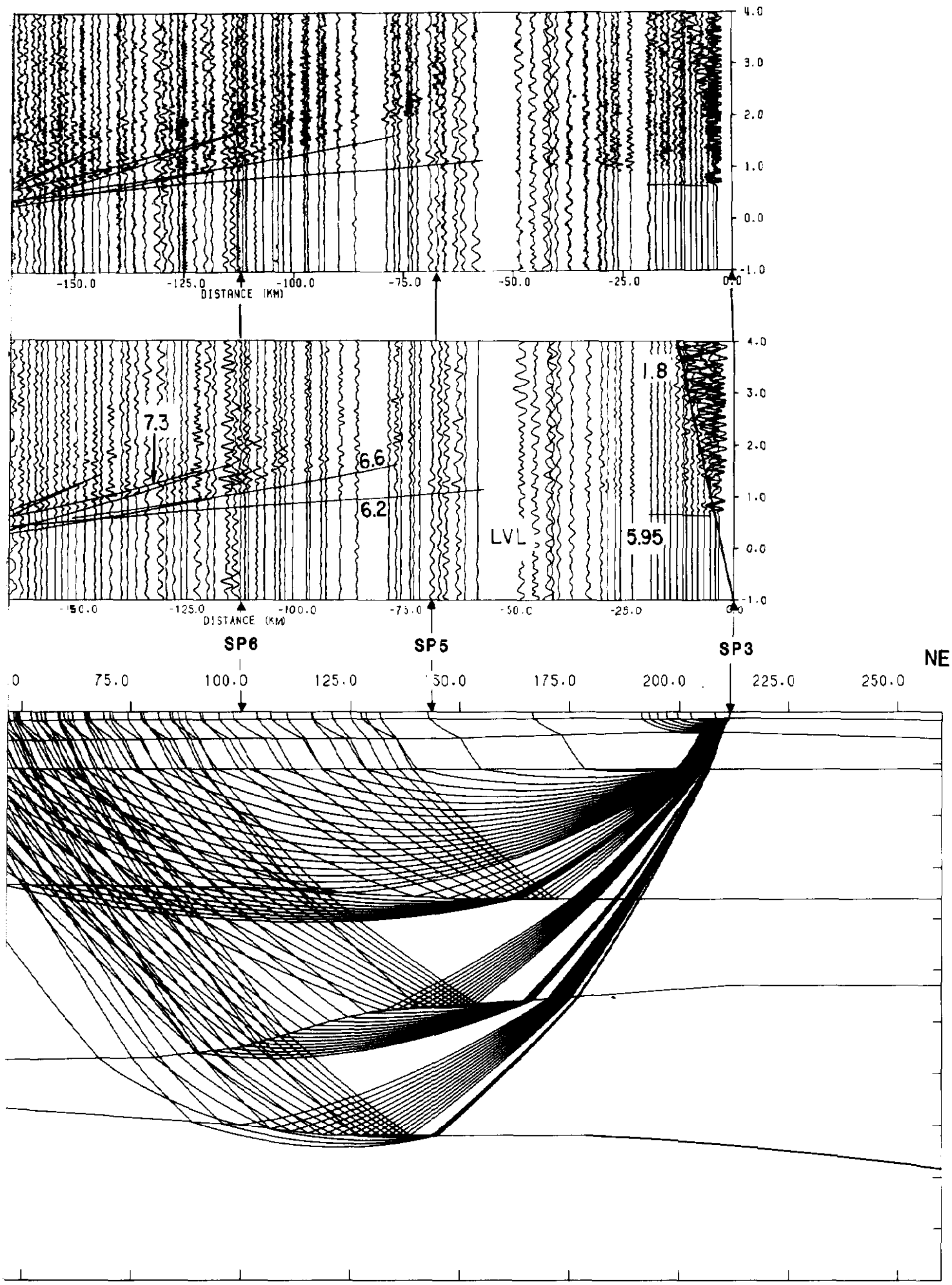


Fig. 3. Axial profile: record sections norn
both refracted and reflected rays are sho
km/s/km. True-amplitude seismograms a
record sections to show the agreement be
The rapid attenuation of the 5.95 km/s a
layer. Strong wide angle reflections show
and thins to the south, and the mantle de

MENT AXIAL PROFILE SP3



nalized (top) and at true amplitude (middle), and model and ray diagram (bottom) for shot point 3. Ray paths for
vn. The velocity at the top of each layer is indicated; layers have a vertical velocity gradient of approximately 0.01
re scaled by distance and filtered 2–10 hz. The travel-time curves calculated from the model are superimposed on the
tween the model and the data. Velocities indicated for travel-time curves are layer velocities not apparent velocities.
rrivals beyond 20 km and the delay in time of the 6.2 km/s arrivals are diagnostic of an upper-crustal low-velocity
deep crustal layers with velocities of 6.6 and 7.3 km/s and the crust–mantle boundary. The 7.3 km/s layer deepens
pth decreases.

MISSISSIPPI EMBAYMENT AXIAL PROFILE SP6

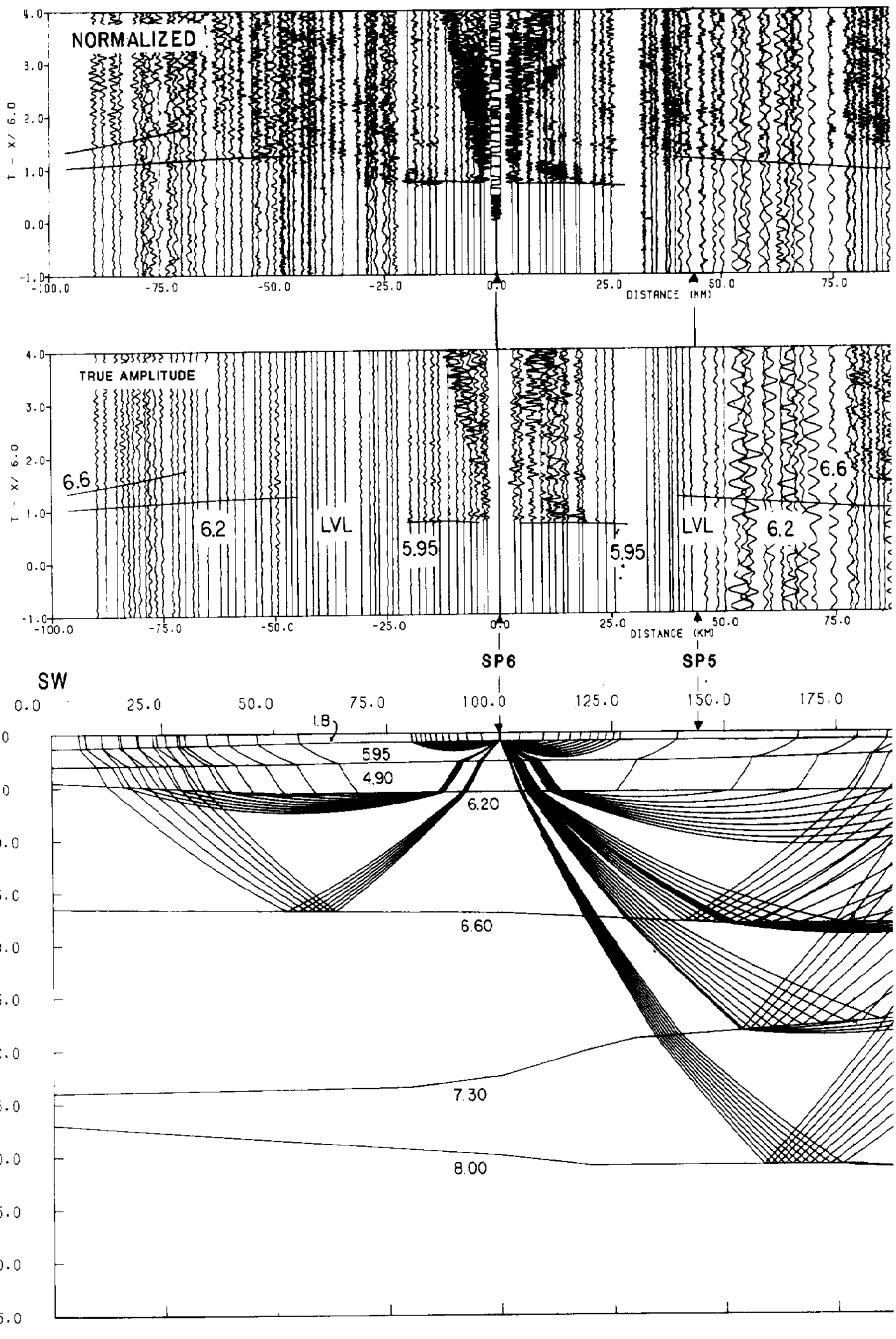
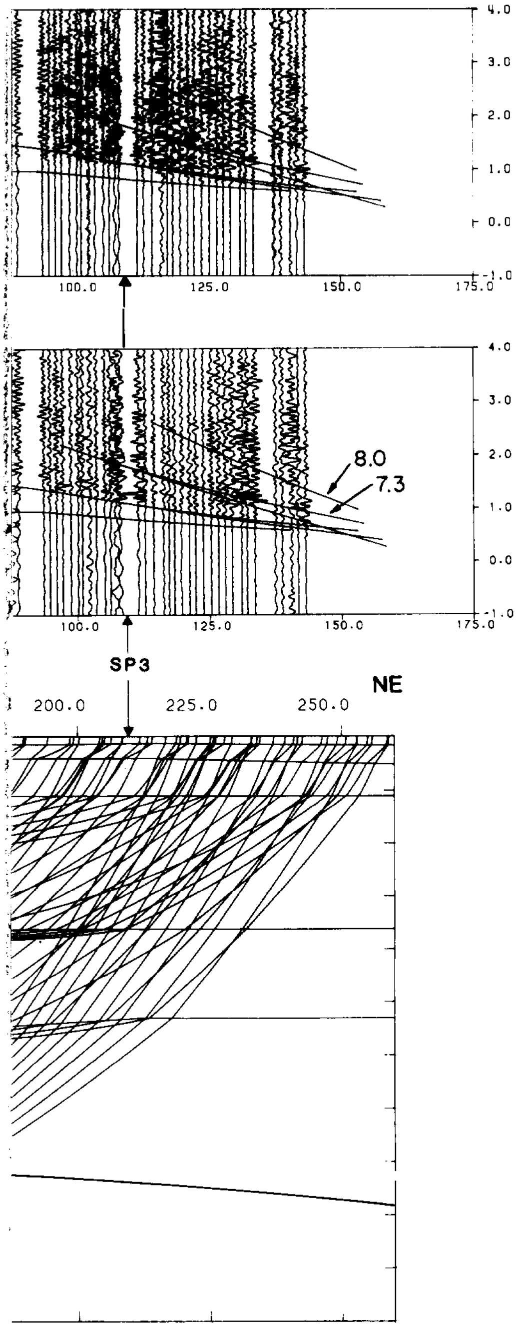


Fig. 4. Axial profile: record sections normalized (top) and at true amplitude (middle), and model and ray diagram (bottom) northeast reverses the profile from shot point 3 (Fig. 3). Data and model presentation are as described in Fig. 3. The st arrivals and the time delay of the 6.2 km/s arrival indicate an upper-crustal low-velocity zone. Deep crustal arrivals witł evident on the profile to the northeast. Due to its short length, the profile to the southwest did not record arrivals from



for shot point 6. The profile to the
rong attenuation of the 5.95 km/s
velocities of 6.6 and 7.3 km/s are
layers beneath the 6.6 km/s layer.

TABLE I

Shot point locations

Shot point	Latitude	Longitude
1	36 36 25.2	89 09 47.8
2	36 56 07.7	90 13 42.9
2 (alternate)	36 53 37.5	90 14 44.6
3	36 24 43.4	89 25 13.0
4	36 05 22.8	88 55 26.2
5	35 58 03.8	89 55 42.3
6	35 41 40.6	90 17 19.2
7	34 32 07.3	91 28 01.7
8	36 09 14.2	91 07 40.0
9	35 17 22.9	89 34 45.1

An interpretation of the axial line (shot points 3–5–6), the flank profile (shot points 2–8), and three of the cross profiles (shot points 2–3–4, 8–6–9, and 8–5–4) is presented by Ginzburg et al. (1982). We here present an interpretation of the two additional cross lines connecting shot points 2–5–9 and 8–3. We also review the results of the interpretation of the axial line because its central location serves to constrain the cross profiles.

THE AXIAL PROFILE

The profile axial to the Embayment graben comprises reversed and overlapping segments from shot points 1, 3, 5, 6, and 7 (Fig. 2). Within 1 km of shot point 3 (Fig. 3), first arrivals travel with a velocity of 1.8 km/s. Beyond one km, the 1.8 km/s phase is overtaken by refractions with an apparent velocity of 5.95 km/s. A conspicuous feature of this profile is the rapid attenuation of the 5.95 km/s arrivals beginning at about 20 km. Beyond 65 km, a 6.2 km/s phase arrives, delayed approximately 0.3 s relative to an extrapolation of the 5.95 km/s phase. Thus, the interval 20–65 km from the shot point constitutes a shadow zone, which is the result of a low-velocity layer between the 5.95 and 6.2 km/s refractors. A velocity of 4.9 km/s has been assigned to the low-velocity layer, based on unpublished sonic logs from the Embayment.

Beyond 70 km, a refraction with an apparent velocity of 6.6 km/s appears, followed in time by arrivals with an apparent velocity of 7.3 km/s. The 6.6 km/s phase has highest amplitude between 90 and 125 km and the 7.3 km/s phase has highest amplitude between 110 and 165 km. Since the lines were not designed to record at P_n range, mantle refractions are not observed. Mantle reflections are present beyond 150 km. Thus, crustal thickness is a measured value and mantle velocity is an assumed value (8.0 km/s).

Arrivals observed along the split profile at shot point 6 (Fig. 4) are consistent with the velocity model derived for shot point 3. In both directions, there is a shadow zone 25–50 km from the shot point and the 6.2 km/s phase is delayed approximately 0.5 s with respect to an extrapolation of the 5.95 km/s arrival. This observation, and data from other axial shot points, confirms that an upper crustal low-velocity layer is a regional feature in the Embayment graben.

Between shot points 5 and 3 (Fig. 3 and 4), the crust along the axial line is nearly laterally homogeneous. The 1.8 km/s layer ranges in thickness from 0.7 to 1.1 km. The 5.95 km/s layer is 2 km thick and underlain by a 3-km-thick low-velocity layer. The 6.6, 7.3, and 8.0 km/s layers have depths of 18, 28, and 41 km, respectively. South of shot point 5, the velocity layering is homogeneous down to the 6.6 km/s layer. The 7.3 km/s phase has a significantly lower apparent velocity which suggests that this layer dips steeply to the southwest. The dip is confirmed by the data from shot point 5 and cross profile 8–6–9 (Ginzburg et al., 1982).

THE CROSS PROFILES

Profile 2–5–9

Profile 2–5–9 strikes south-southeast from the northwestern edge of the Embayment and crosses the axial line at a 60 degree angle. At shot point 2 (Fig. 5), first arrivals have a small intercept time (approximately 0.1 s) due to thinning of the 1.8 km/s layer toward the edge of the Embayment. First arrivals can be traced 70 km without a break or delay, which indicates that the low-velocity layer is not present near this shot point (Fig. 5 and 6). The energy distribution of the synthetic seismogram is consistent with the observed true-amplitude data (Fig. 5). The 6.6 km/s phase begins at 120 km, followed by a relatively high-amplitude 7.3 km/s phase. Mantle reflections are visible between 140 and 170 km.

At shot point 9 (Fig. 6), the intercept times of the first arrivals indicate that the 1.8 km/s layer is approximately 0.65 km thick. First arrivals from the 5.95 km/s and 6.2 km/s layers are clearly visible to 50 km. From 60 to 100 km, amplitudes of the arrivals from the 6.2 km/s layer are attenuated by interaction with the axial low-velocity layer, and arrivals from the 6.6 km/s layer are difficult to discern. Beyond 110 km the 7.3 km/s phase is clearly recorded but the mantle reflection is only intermittently observable.

The crustal model for profile 2–5–9 (Fig. 5) depicts the low-velocity layer confined to a 70-km-wide zone near the axis of the Embayment. The base of the 5.95 km/s layer is planar at a depth of 3 km. The 6.6 km/s layer has a slight south-southeastward dip and an average depth of 18 km. The 7.3 km/s layer rises to a minimum depth of 28 km beneath the axial profile and dips gently toward the margins of the Embayment.

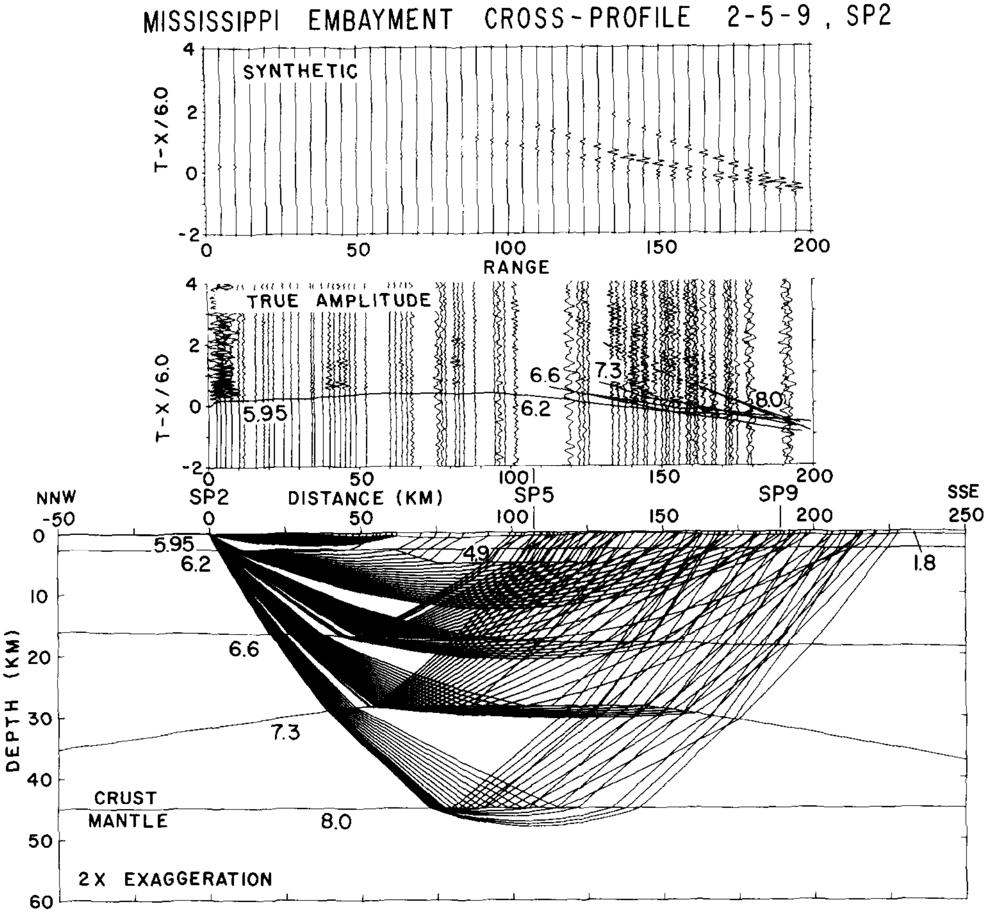


Fig. 5. Cross profile 2–5–9: model and ray diagram (bottom), true amplitude record section (middle) and ray theoretical synthetic seismograms (top). Data and model presentation are as described in Fig. 3. A low-velocity layer (4.9 km/s) is shown in the center of the model. The first arrivals to a distance of 150 km refract through near-surface Paleozoic rocks (5.9 km/s) and crystalline basement (6.2 km/s). Beyond 120 km, clear wide-angle reflections are evident from crustal layers with velocities of 6.6 and 7.3 km/s, and from the crust–mantle boundary. Synthetic seismograms are plotted with the same distance scaling as the observed data and show good agreement, particularly in the amplitudes of the wide-angle reflections.

Profile 8–3

Profile 8–3 strikes nearly east-west and intersects the axial profile at about a 45 degree angle (Fig. 2). The data from shot point 8 (Figs. 7&8) are similar to the data from shot point 2: the 1.8 km/s layer is very thin as indicated by the near zero intercept time, and the low-velocity layer evidently is not present near the shot point. Consistent with the synthetic seismograms, the data show a weak but continuous 6.2 km/s refraction and high-amplitude arrivals from the boundaries of the 6.6 km/s

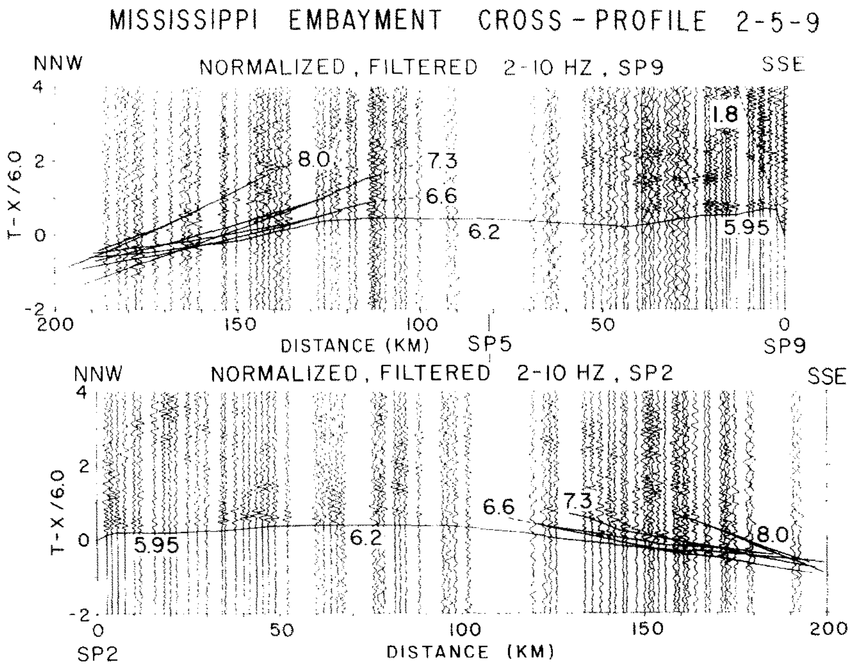


Fig. 6. Cross profile 2–5–9: normalized record sections for shot point 9 (top) and shot point 2 (bottom). The calculated travel-time curves on the record sections are for the model shown in Fig. 5. Velocities indicated are layer velocities not apparent velocities. Low amplitude arrivals that are not visible in the true-amplitude record sections (Fig. 5) can be identified in these record sections.

layer and the mantle (Fig. 7). These features are repeated on the reverse profile from shot point 3 (Fig. 8), and in addition, the low-velocity layer is clearly evidenced by the rapid amplitude decay of the 5.95 km/s refractor.

The crustal velocity model for profile 8–3 (Fig. 7) indicates that the low-velocity layer is present along the axis of the Embayment and that the 7.3 km/s layer rises to a depth of 27 km beneath it. The 6.6 km/s layer dips gently toward the east and the 7.3 km/s layer dips more steeply toward the western margin of the Embayment.

GRAVITY MODELS

Two of the crustal velocity models for the Embayment have been converted to density models to check for agreement with the observed Bouguer gravity. The velocity–density relationship of Birch (1961) was used for the lower crust, and the densities cited by Cordell (1977) were used for the 1.8 and 5.95 km/s layers. Bouguer gravity values are from Hildenbrand et al. (1977).

The velocity model of the axis of the Mississippi Embayment (Figs. 3 and 4) indicates northward thinning of the unconsolidated sediments and a rising and

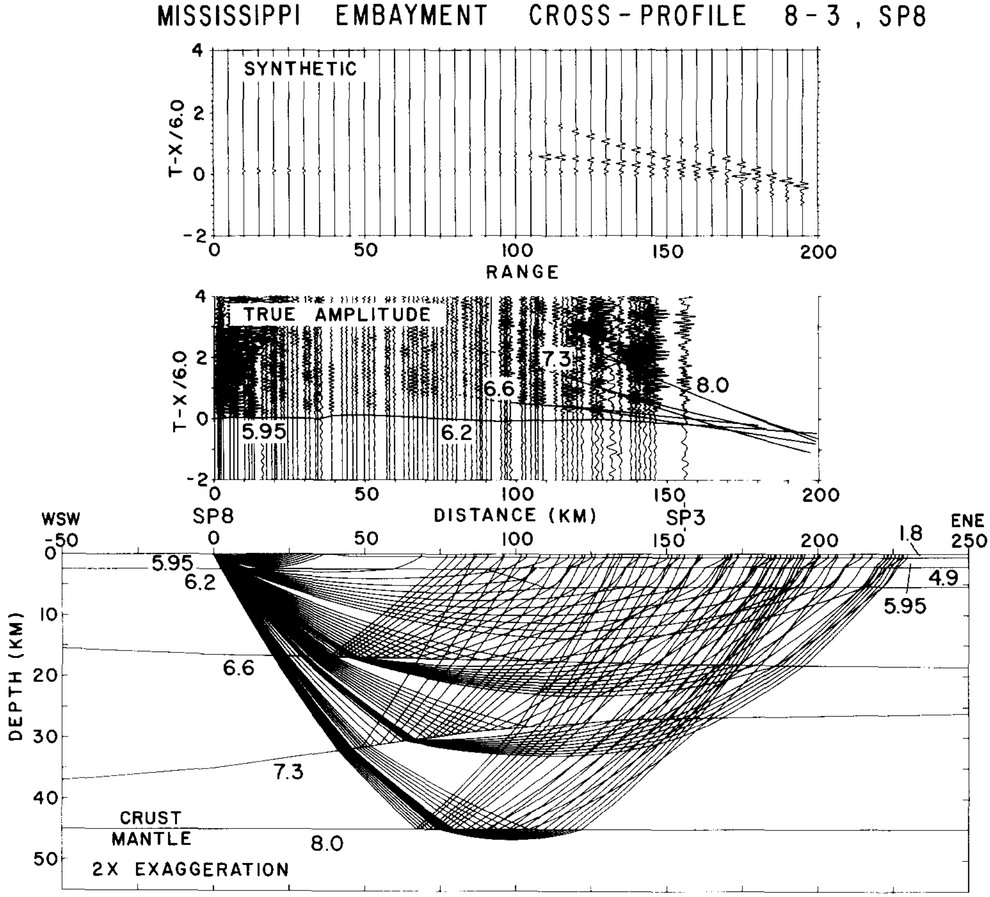


Fig. 7. Cross profile 8–3: model and ray diagram (bottom), true amplitude record section (middle) and synthetic seismograms (top). Presentation as described in Fig. 3. Deep crustal reflections from the 6.6 km/s layer have high amplitudes beyond 100 km; the 7.3 km/s reflections are clear from 110 km to the end of the profile. Observed amplitudes of the PmP reflections are larger than the synthetic seismograms possibly due to a focusing effect.

thickening of the 7.3 km/s layer. To satisfy the gravity data (Fig. 9) these two features are compensated by a deepening of the mantle from 37 km in the southern Embayment to nearly 44 km in the north, a feature also determined from the seismic data (Ginzburg et al., 1982). The seismic and gravity data are therefore consistent in showing strong lateral change in crustal structure along the axis of the Embayment, with the major change occurring in the 7.3 km/s layer. Local gravity highs are ascribed to high density intrusives (shaded in Figs. 9 and 10) as described by Hildenbrand et al. (1977).

The second density model (Fig. 10) is along the cross profile between shot points 2 and 9. In this model the low-velocity layer (density 2.55 g/cm^3) is restricted to the

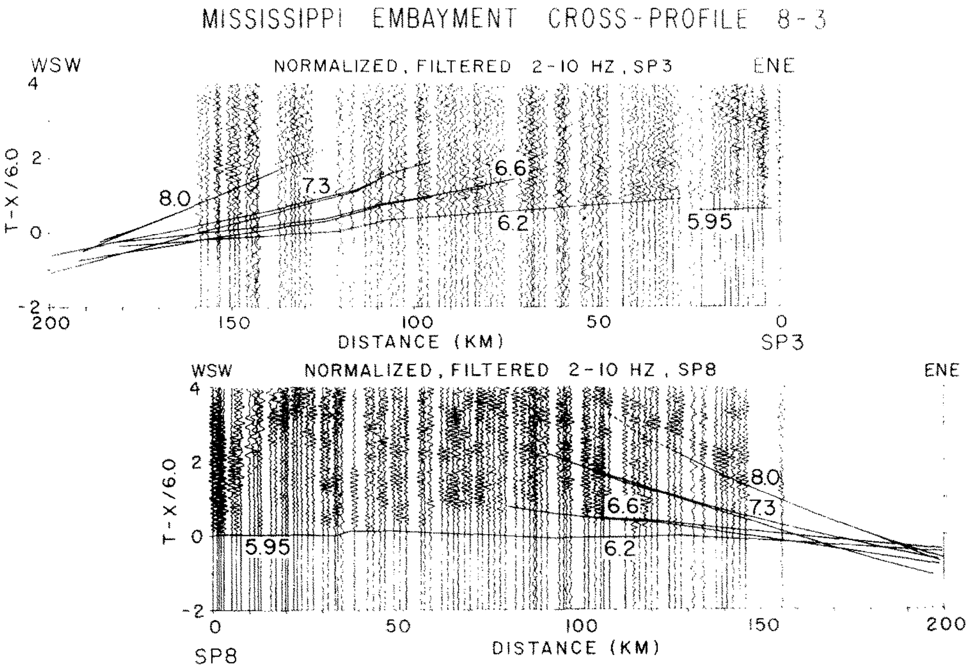
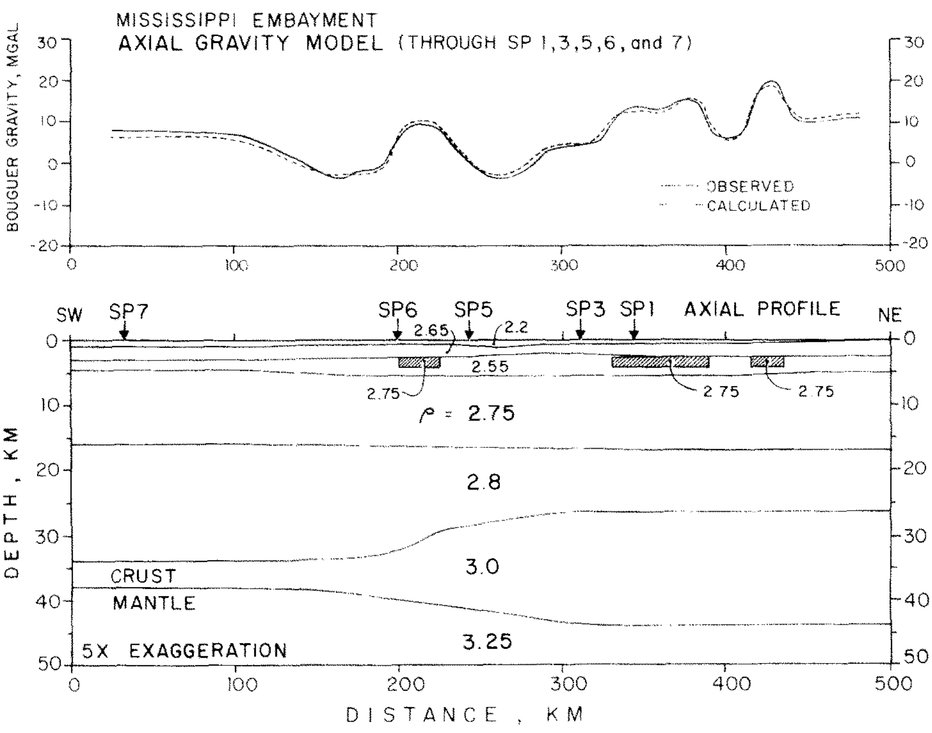


Fig. 8. Cross profile 8–3: normalized record sections for shot point 3 (top) and shot point 8 (bottom). The calculated travel-time curves are for the model shown in Fig. 7. Velocities indicated are layer velocities not apparent velocities.



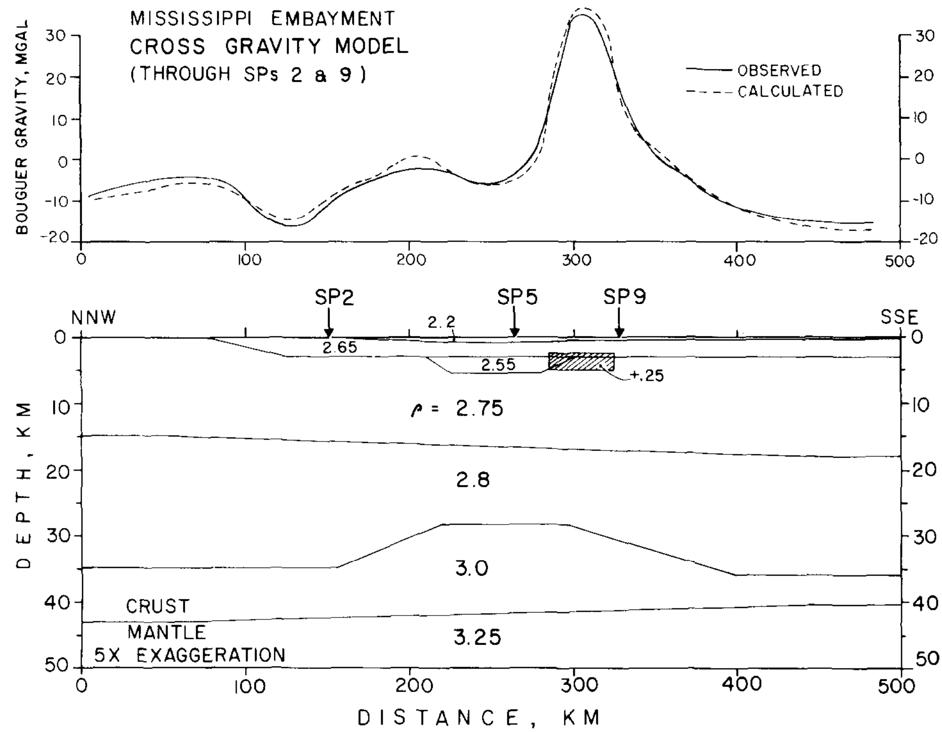


Fig. 10. Crustal density model (bottom) and observed and calculated Bouguer gravity (top) for the cross profile through shot points 2, 5 and 9. Presentation as described in Fig. 9. The Embayment low-velocity layer (2.55 g/cm^3) is restricted to the middle of the model and the high density basal crustal layer (3.0 g/cm^3) rises beneath the axis of the graben.

center of the Embayment and the lower crustal layer (3.0 g/cm^3) forms a dome with a width at its base of 250 km (Fig. 10). The mantle dips to the northwest, reaching a depth of 43 km beneath the St. Francois Mountains (Fig. 1).

In summary, the seismic refraction and the Bouguer gravity data have been interpreted in consistent models along and across the Embayment. The gravity cross profile is a refinement of the cross profile of Ervin and McGinnis (1975), who had less seismic data available to control their model.

Fig. 9. Crustal density model (bottom) with observed and calculated Bouguer gravity (top) for the axial profile through shot points 1, 3, 5, 6 and 7 (Fig. 2). The density model has been constructed from the seismic velocity model of Figs. 3 and 4. Bouguer gravity data from Hildenbrand et al. (1977). Densities in g/cm^3. The layer with a density of 2.55 g/cm^3 is a low-velocity layer in the upper crust. The 3.0 g/cm^3 layer represents the anomalous high-velocity layer at the base of the crust. Three intrusive bodies with densities of 2.75 g/cm^3 are indicated in the upper crust.

DISCUSSION OF REFRACTION AND GRAVITY RESULTS

The crustal structure of the Mississippi Embayment consists of six primary layers. Based on regional surface geology and borehole data, the lithologies of three of the layers are identified as: loosely consolidated Tertiary and Cretaceous sedimentary deposits (1.8 km/s), Paleozoic carbonate and clastic sedimentary rocks (5.95 km/s), and granitic upper crust (6.2 km/s). The lithologies of the other three layers can be inferred from geologic and geophysical measurements in regions with similar crustal velocity structure. The 4.9 km/s low-velocity layer most likely represents clastic sediments. The lower layers correspond geologically to metamorphic lower crust (6.6 km/s) and modified lower crust (7.3 km/s).

Two of these layers represent departures from a standard continental crust and are important to the interpretation of the Embayment as a continental rift. The first is the low-velocity layer overlying the crystalline crust. Our model clearly indicates that this low-velocity layer is of maximum thickness (3 km) within the basement graben defined by gravity and aeromagnetic data (Hildenbrand et al., 1977; Kane et al., 1981). The lithology of this layer is not known, but the low velocity is indicative of clastic sedimentary rocks. The layer may consist of Early Paleozoic marine shales, similar to those encountered in deep bore holes in the Rough Creek Graben (Fig. 1.; Schwalb, 1980).

The second departure from a standard continental crust is the 7.3 km/s layer. McCamy and Meyer (1966), Ervin and McGinnis (1975), Austin and Keller (1982), and others suggest that the Mississippi Embayment is underlain by a high-velocity basal crust that is the result of alteration by injection of mantle material. The present work provides information on the three-dimensional structure of this basal layer. Along the axial profile, the 7.3 km/s layer rises to a depth of 27 km between shot points 5 and 3 and plunges steeply to the southwest (Figs. 3, 4 and 9). On the cross profile, the layer dips gently to the northwest and southeast, reaching depths on the order of 35 km at the margins of the Embayment. Thus, the 7.3 km/s layer may form a dome beneath the Reelfoot Basin (Fig. 1). Although the dip of the 7.3 km/s layer is not well constrained by seismic data, particularly on the southeastern slope, the gravity models substantiate these results.

If the thickening of the 7.3 km/s layer beneath the Reelfoot basin is considered the result of a Precambrian mantle plume, the Embayment may be viewed as an arm of a triple junction, the second arm extending through the Rough Creek Graben and the third between the St. Francois Mountains and the Sangamon Arch (Fig. 1). This suggested location of a triple junction differs from the southern Mississippi location proposed by Burke and Dewey (1973), but is essentially the same as that of Kumarapeli and Saull (1966) and Braile et al. (1982).

Unlike the model proposed by Ervin and McGinnis (1975), our seismic and gravity models indicate that the boundary between the upper and lower crust has remained planar despite thickening of the altered lower crust and the formation of a basement graben (Figs. 3, 5, 7, 9 and 10). This 6.2-6.6 km/s velocity discontinuity may be a metamorphic boundary which has become planar as the Embayment crust cooled. Thus, changes in the midcrust in response to rifting have been obscured by metamorphism. Alternatively, the upper crustal layer may have been uniformly extended during rifting, resulting in a thinner but still planar mid-crust. Although the origin of a planar boundary is uncertain, the observation is an important constraint on models of the mechanism of rifting in the Mississippi Embayment.

COMPARISON WITH OTHER CONTINENTAL RIFTS

In the following section, we compare the crustal structure of the Mississippi Embayment to other continental rifts. Although the rifts discussed below are younger than the Mississippi Embayment, there are several important similiarities in structure. In each case a normal crust composed of a 6.2 and 6.6 km/s layers has been modified to include a high-velocity basal crust. The surface expression of rifting is a graben which is filled with low velocity sediments. The comparison of continental rifts emphasizes the role of deep crustal processes in rift genesis (see also Olsen, 1983, this volume).

The Rhinegraben

Seismic refraction studies have been conducted for over a decade in the Rhinegraben area of Germany, with the most detailed work done in the southern portion of this rift zone (Edel et al., 1975; Prodehl, 1976). A cross section of the southern Rhinegraben with isovelocity lines is shown in Fig. 11-2. The crust–mantle boundary rises from 30 km in the west to 26 km beneath the graben forming a wide arch with a span of 150–180 km. Outside the graben, the crust–mantle transition is a first-order discontinuity for which the 7.5–8.0 km/s isovelocity lines converge. Beneath the graben proper, the crust–mantle transition is continuous, and the 7.2–7.8 km/s isovelocity lines warp steeply upward to produce a zone of high velocity gradient beginning at a depth of 21 km. If we assume a mantle depth of 26 km, the whole depth range with velocities between 7.2 and 7.8 km/s may be considered a zone of crust-mantle interaction similiar in origin to the 7.3 km/s layer observed in the Mississippi Embayment (Fig. 11-1).

The 2–3 km thickness of alluvium in the Rhinegraben is comparable to the thickness of the low-velocity layer in the Embayment. In addition, both rifts retain an average upper crustal velocity of 6.2 km/s. This suggests that in the Rhinegraben and in the Mississippi Embayment, doming of an altered lower crust resulted in 2–3 km of displacement at the surface without affecting the velocity of the upper crustal material.

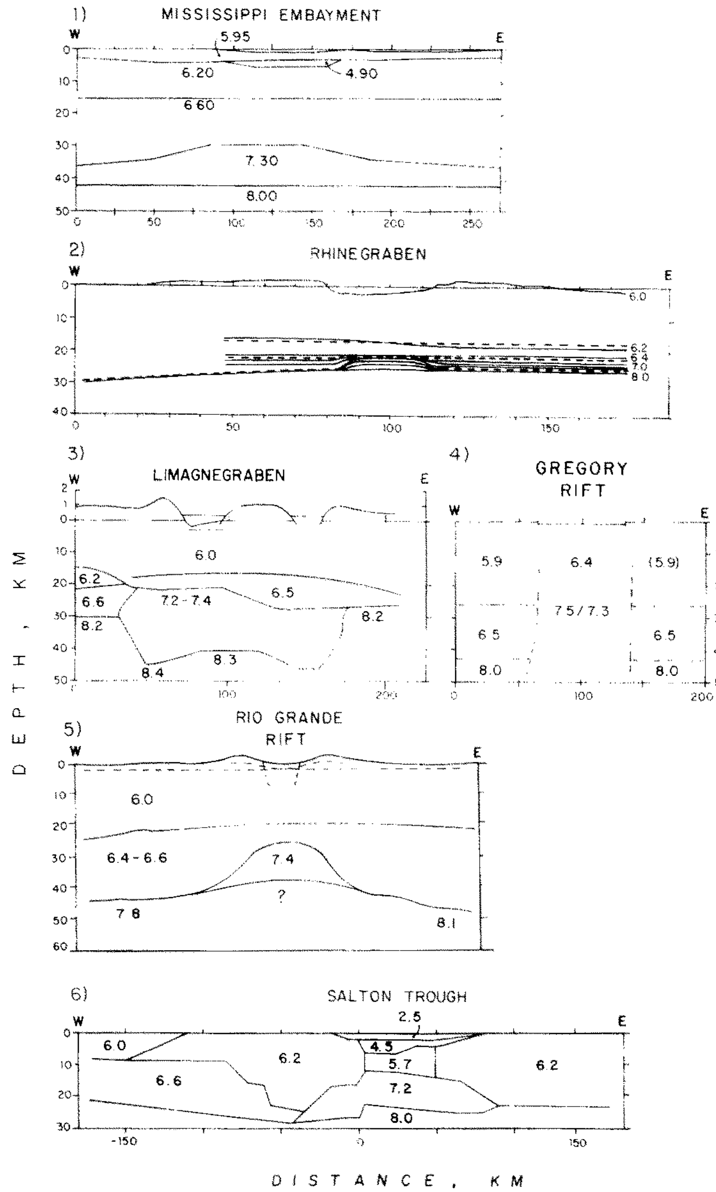


Fig. 11. Comparison of the crustal velocity structure of the Mississippi Embayment with other rifts: (1) Mississippi Embayment (this study and Ginzburg et al., 1982); (2) Rhinegraben (Edel et al., 1975), dashed lines: main crustal boundaries; solid lines: isovelocity contours; (3) Limagnegraben (Hirn and Perrier, 1974); (4) Gregory Rift, East Africa (Griffiths et al., 1971; Long, 1976; Long et al., 1973); (5) Rio Grande Rift (lower crust modified from Cook et al., 1979, upper crust from Keller et al., 1979); (6) Salton Trough (Fuis et al., 1982, 1983).

The Limagnegraben

Hirn and Perrier (1974) have interpreted the crustal structure of the Limagnegraben of Southern France from seismic refraction data. Although the structure is more complex, the primary crustal features are similar to the Mississippi Embayment (Fig. 11-3). The sedimentary fill of the Limagnegraben is comparable in thickness to the low-velocity layer of the Embayment. The upper crust retains a normal crustal velocity of 6.0 km/s and has not been affected by rifting. As in the Embayment, an anomalous lower crustal layer with a velocity of 7.2–7.4 km/s has replaced 8 km of the lower crust. However, the mantle has been deepened approximately 15 km relative to the flanks of the graben, a feature not observed in the Embayment structure.

The Gregory Rift

The Gregory Rift is part of the presently active East African Rift System. An unreversed refraction profile recorded along the rift axis (Griffiths et al., 1971) shows an upper crustal layer with a velocity of 6.4 km/s overlying a 7.3–7.5 km/s layer at a depth of 20 km (Fig. 11-4). Off the rift axis, earthquake arrival times indicate a shield type crust of two layers underlain by normal mantle material (Long, 1976; Long et al., 1973). The relatively high velocities in the upper crust along the axis of the rift suggest that rifting and the concomitant alteration of the crust have proceeded to a later stage than in the Mississippi Embayment. The 7.3 km/s layer presumably represents a mixture of normal continental crust (6.5 km/s) and mantle derived material, as in the Embayment.

The Rio Grande Rift

The crustal structure of the Rio Grande Rift has been interpreted from gravity data, seismic reflection and refraction profiles, and earthquake data (Sanford et al., 1973; Ramberg et al., 1978; Olsen et al., 1979; Cook et al., 1979; Keller et al., 1979). On the basis of wide-angle reflections and refractions, Cook et al. (1979) propose a lower crustal replacement model for the Rio Grande Rift. The model consists of an upper crust (6.0 km/s) overlying a lower crustal layer (6.5 km/s) and a basal crustal layer with a velocity of 7.4 km/s (Fig. 11-5).

Crustal models based on a refraction profile (Olsen et al., 1979) and surface wave data (Keller et al., 1979), suggest thinning of the crust beneath the Rio Grande Rift without a basal crustal high-velocity layer. We attach particular significance to the basal layer model of Cook et al. because it correlates well in depth and velocity with the 7.3 km/s layer found in the Mississippi Embayment. A detailed refraction survey of the Rio Grande Rift would allow resolution of the lower crustal structure.

The Salton Trough

The Salton Trough is an example of a fully developed continental rift. Lomnitz et al. (1970), Elders et al. (1972) and Fuis et al. (1982) describe its rifting mechanism as a continuation of the ridge–transform-fault spreading system that begins in the Gulf of California. Seismic refraction data indicate velocities less than 5.8 km/s to a depth of 12 km in the center of the trough and 6.0–6.2 km/s velocities on the flanks. The low velocities are the result of the rifting open of the crust and the creation of a new crustal column. The 2.5 and 4.5 km/s layers consist of young sediments. The low basement velocity (5.7 km/s) suggests that the basement of the trough consists of metasediments that infilled during rifting (Fuis et al., 1982, 1983). Granitic basement (6.0–6.2 km/s) occurs on the flanks. In the lower crust, mantle derived material has risen along the axis of the trough and a velocity of 7.2 km/s is found, as in the Mississippi Embayment.

CONCLUSIONS

The crust of the northern Mississippi Embayment includes two layers that represent departures from a standard continental crust: a low-velocity layer (4.9 km/s) in the upper crust and an anomalous high-velocity layer (7.3 km/s) at the base of the lower crust. The low-velocity layer is approximately 3 km thick and lies within a northeast-trending basement graben of estimated Early Paleozoic age. The low velocity and spatial configuration of this layer suggest that it consists of sediments deposited in the graben after rifting. The presence of a 7.3 km/s layer indicates that the lower crust has been altered by injection of mantle material. The 7.3 km/s layer thickens in the north-central Embayment, thins gradually to the northwest and southeast, and more rapidly to the southwest along the axis of the graben. Comparison with other rifts shows that both the upper crustal graben and the altered lower crust are common features of continental rifts. The presence of these features confirms suggestions that the Mississippi Embayment is the site of an ancient continental rift. In addition, the apparent doming of the 7.3 km/s layer to the northeast suggests that rifting in the Mississippi Embayment may be the result of a triple junction centered in the Reelfoot Basin area.

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