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THE WICHITA MAGNETIC LOW, SOUTHEASTER KANSAS

by

W. V. Meyer

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THE WICHITA MAGNETIC LOW, SOUTHEASTERN KANSAS

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ABSTRACT

Meyer, William Vincent. M.S., Purdue University, August 1987. The Wichita Magnetic Low, Southeastern Kansas. Major Professor: William J. Hinze.

Several hypotheses have been proposed concerning the source of a linear, east-west trending magnetic low and a correlative boundary between basement Precambrian terranes of different ages and lithologies in southern Kansas. The Wichita Magnetic Low is an accentuated and broadened segment of the regional, linear magnetic minimum in southeastern Kansas. No distinct gravity anomalies, correlative with the magnetic low, are observed. Analysis of gravity and magnetic data with isolation and enhancement techniques and modeling demonstrates that the Wichita Magnetic Low may be interpreted as the geophysical expression of a southerly-dipping suture between two contrasting magnetic terranes that have similar densities and associated shallow, nearly non-magnetic Graniteville-type plutons that extend to midcrustal depths.

I.INTRODUCTION

Based on drill hole data Van Schmus and Bickford (1981) noted a distinct east-west demarcation between two predominantly different basement terranes in eastern Kansas. Based on this geological information and spectral analysis of aeromagnetic data in Kansas, Yarger (1981) proposed that a suture zone occurs in a line from eastern Colorado, across Kansas, and into Missouri. This suture zone is best delineated by a linear series of discontinuous magnetic lows transecting the state of Kansas (Figure 1). The "Wichita Magnetic Low" (Yarger, 1983) is a prominent, oval-shaped, negative magnetic anomaly in southeastern Kansas which occurs in the hypothesized suture zone of Yarger (1983) (Figure 2). Elongate, high-wavenumber, negative magnetic lows with conspicuous marginal highs are superimposed upon this low. Gay (1984) proposed that these magnetic lows within the Wichita Magnetic Low are a result of 'tin-granite' plutons which are similar in nature to tin-granites (Graniteville-type) found in the St. Francois Mountains of Missouri.

Linear, negative, magnetic anomalies, similar to the east-west trending minimum that extends across Kansas, are associated with sutures in the Canadian Precambrian Shield.

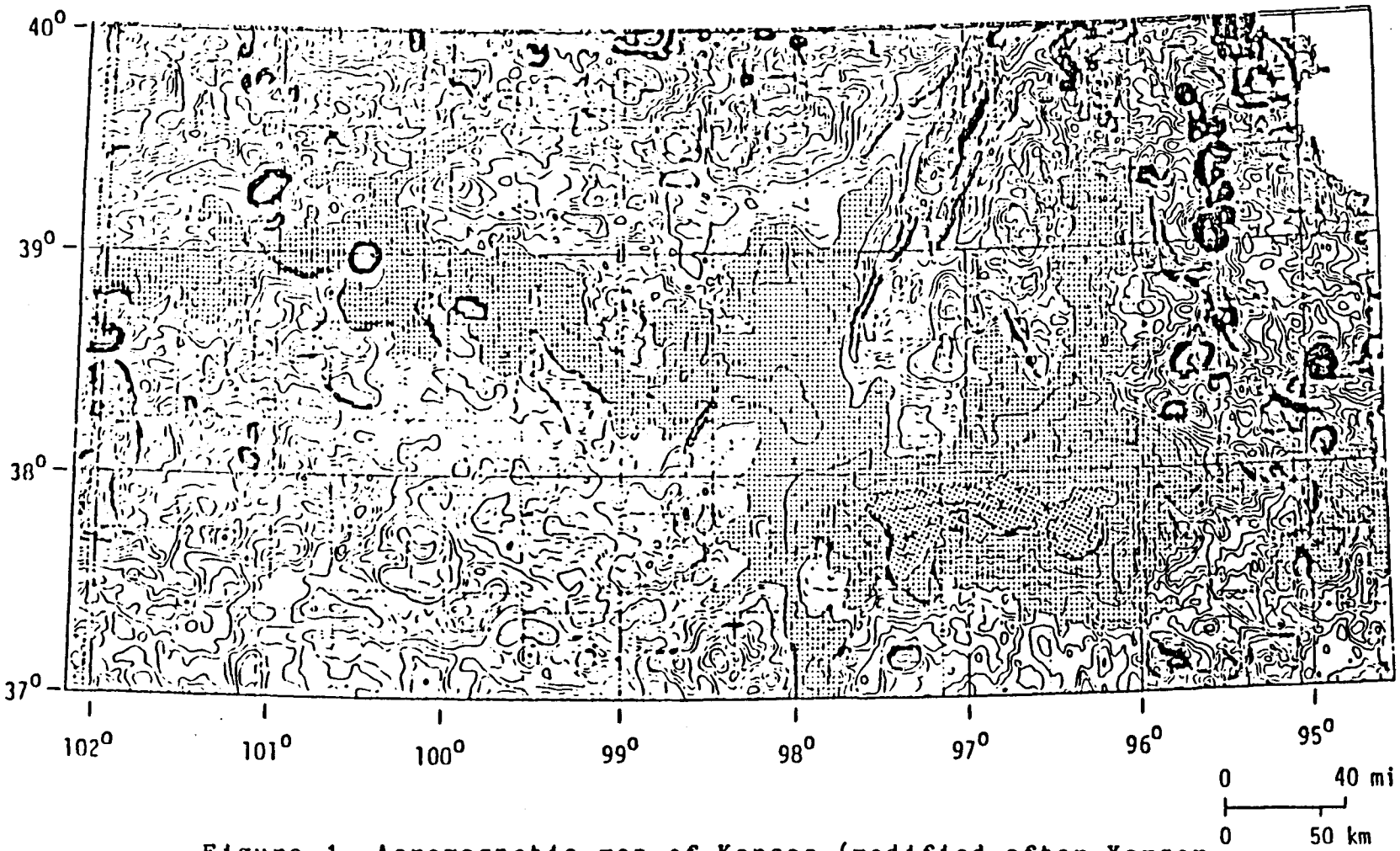

Figure 1. Aeromagnetic map of Kansas (modified after Yarger et al., 1985), light dotted pattern (<2000 gammas) is the regional, linear magnetic low and dark dotted pattern (<800 gammas) is the Wichita Magnetic Low.

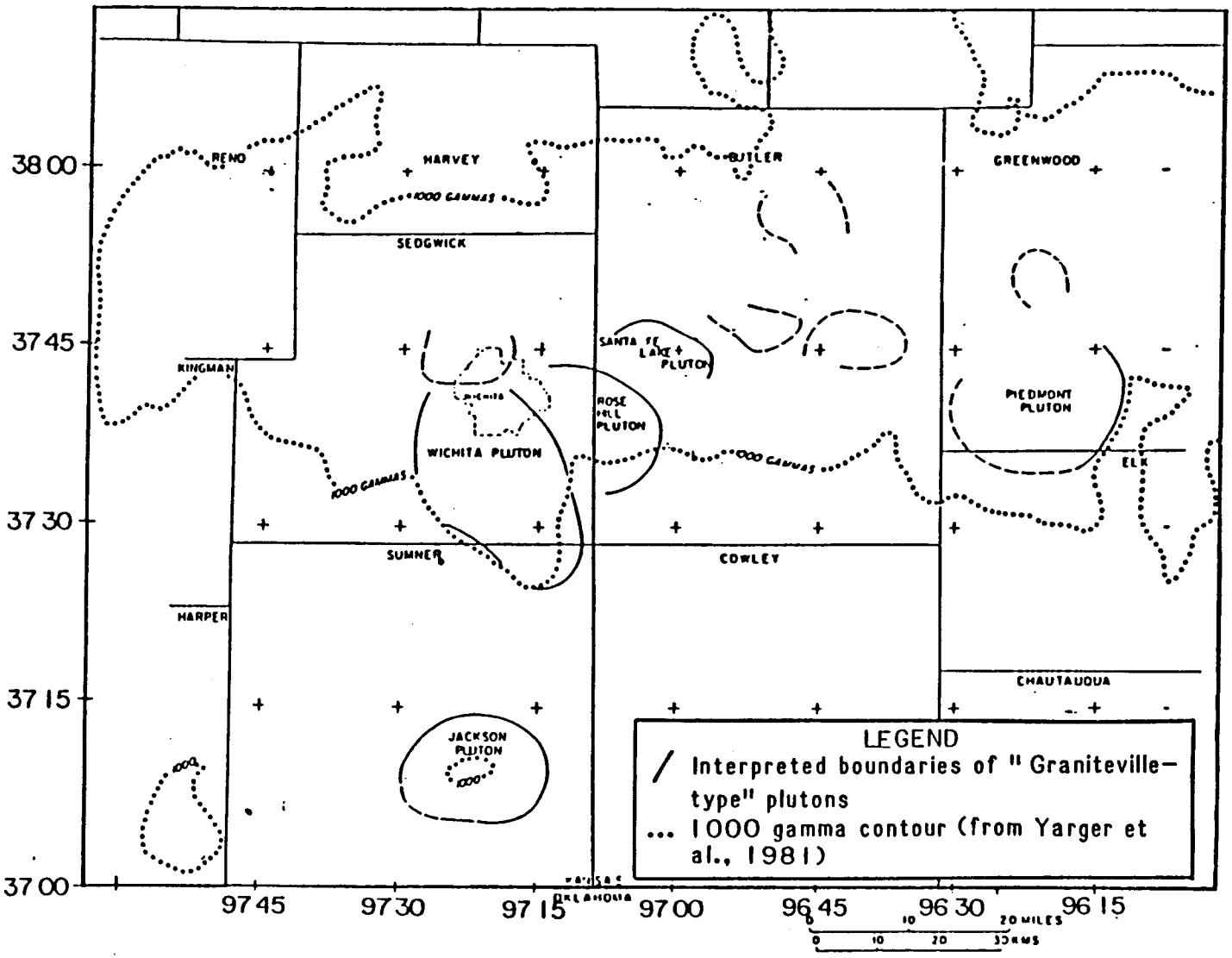

Figure 2. Wichita Magnetic Low with interpretation of the Graniteville-type plutons (modified after Gay, 1984).

The Slave-Churchill suture along the Thelon front (Windley, 1983) and the Grenville cryptic suture (Gibb et al., 1983) are associated with discontinuous linear magnetic lows. Another example of a proposed suture which has a diagnostic linear magnetic low is the Altahama anomaly which separates the Charleston terrane from the northern Florida terrane in the southeastern United States (Higgins and Zietz, 1983). Although these proposed sutures have associated linear magnetic lows, they also have distinct paired gravity anomalies (Gibb et al., 1983) with the exception of the proposed suture in Kansas. The lack of this diagnostic feature focuses attention on the proposed suture in Kansas.

This study investigates the hypothesis that the Wichita Magnetic Low is a result of the combined effects of a suture zone and of emplacement of granitic plutons. The purpose of this investigation is to analyze the geological and geophysical data in order to synthesize an interpretation of the Wichita Magnetic Low. Emphasis will be placed on magnetic and gravity modeling of the Wichita Magnetic Low in conjunction with isolation and enhancement techniques in an effort to separate the long wavelength anomalies due to the hypothesized suture zone (Yarger, 1981) and the short wavelength anomalies due to plutons in this region (Gay, 1984). Direct geologic data, such as drill hole data and isotope age information, as well as

information concerning the nature of the crust from seismic methods will be used where available to aid in constraining the potential field models and to aid in the interpretation.

II. GEOLOGICAL SETTING

An understanding of the regional Precambrian geological setting of the midcontinent is complicated by thick Paleozoic sedimentary rock cover. Therefore the information concerning the underlying Precambrian basement is derived from relatively sparse, clustered drill holes, scattered exposures of the crystalline basement, and geophysical and geochronological data. A bias occurs in basement rock samples because drilling is primarily clustered over basement highs in search of potential petroleum reservoirs and is normally terminated before or shortly after crystalline rock is reached. Exposures of Precambrian rocks within the midcontinent are widely separated, but outcrops such as the St. Francois Mountains of southeastern Missouri provide very important information about the basement of this area. Outcrops of Precambrian rocks along the midcontinental perimeter in the Canadian Shield, the Great Lakes region, and the Rockies are often used to extrapolate the nature of the basement underlying the Phanerozoic sedimentary cover in conjunction with geophysical and geochronological data.

The Precambrian rocks of the midcontinent region can be divided into four general rock types: 1) plutonic

granite and metamorphic rocks similar to those exposed in the Canadian Shield; 2) anorogenic mesozonal granites; 3) rhyolite and epizonal granite; and 4) basalt, gabbro, and sedimentary rocks associated with rifts (Denison et al., 1984). The basement terranes of the midcontinent region of the United States will be discussed chronologically with an emphasis on the basement geology in the central midcontinent. Figure 3 is a compilation of the proposed basement terranes of the midcontinent region which will be overviewed in the following section.

Regional Geology

Archean rocks, defined as those dated at greater than 2500 m.y., are exposed in the Canadian Shield and the Lake Superior region and are traceable with geophysical data by west-southwesterly trends that extend into central North Dakota and northeastern South Dakota. Archean rocks are also found in Wyoming but are separated from those in the eastern Dakotas by younger northerly trending rocks which underlie the western Dakotas and eastern Montana and Wyoming (Denison et al.,1984). Mesozonal granites, granodiorites, gneisses, and greenstone belts are characteristic rock types of the Archean province of the northern midcontinent. A linear trend extending from southern Wyoming to central Wisconsin is inferred as the southern boundary separating predominantly Archean from

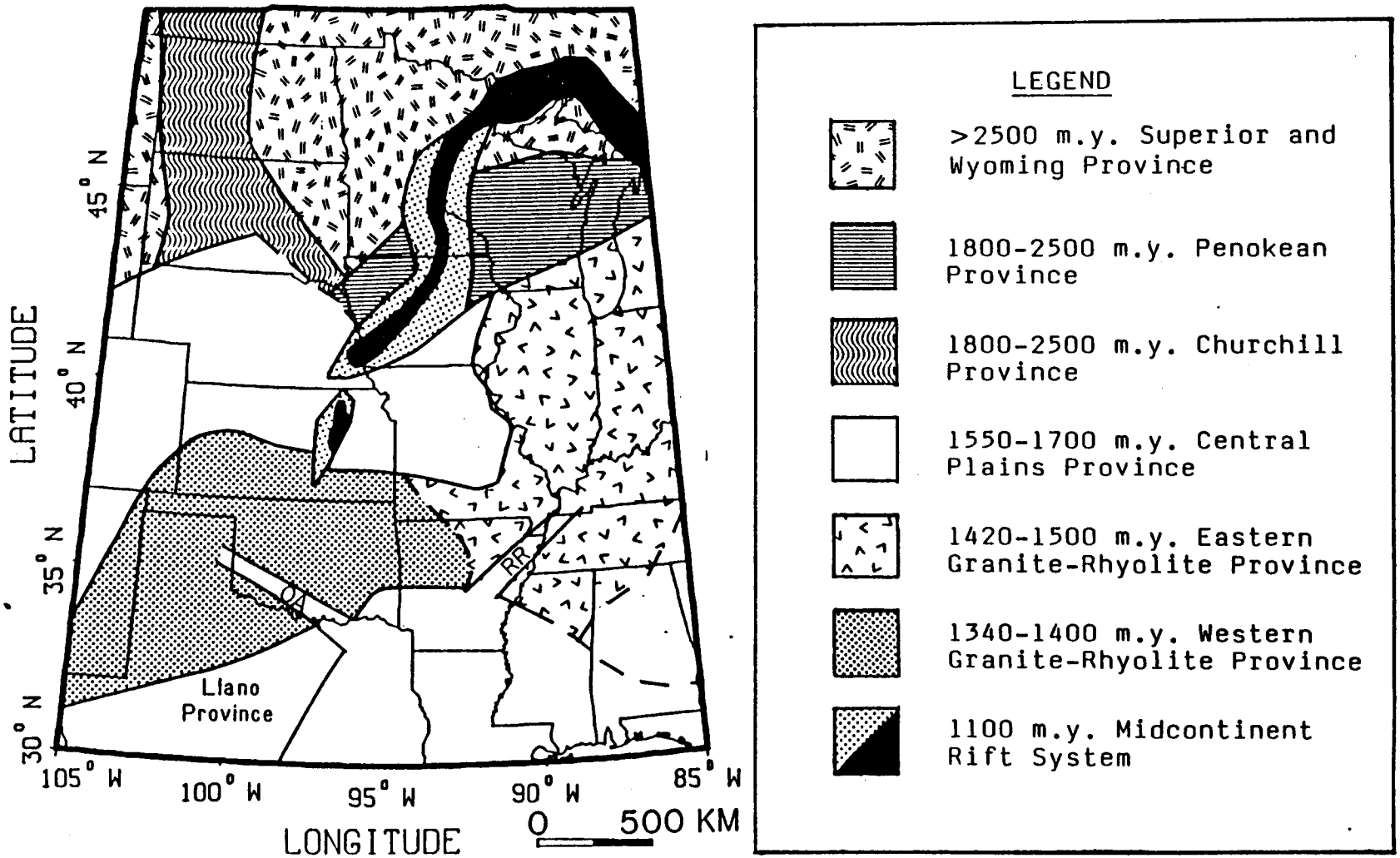

Figure 3. Compilation of basement terranes of the midcontinent (modified from Denison et al., 1984; Bickford et al., 1986; Sims and Peterman, 1986). OA is the Oklahoma Aulacogen and RR is the Reelfoot Rift.

Proterozoic rocks (Goldich et al., 1970; Van Schmus and Anderson, 1977; Hills and Houston, 1979; Van Schmus and Bickford, 1981).

North, northwest-trending magnetic and gravity anomalies truncating the southwestern trends of the Archean Superior Province in the western Dakotas are interpreted as southerly extensions of the Trans-Hudson orogen (Churchill Province) of Canada (Green et al.,1979, 1985). Felsic volcanics, granites, gneisses, and mafic and felsic schists are common rock types with the gneisses predominating in three northwesterly trending metamorphic belts between the two Archean cratons (Denison et al., 1984).

The tectonic history of the Trans-Hudson orogen is controversial. One hypothesis is that this terrane was involved in an orogeny or collision between the two Archean blocks approximately 1700-1900 m.y. ago (Goldich et al.,1966; Dutch, 1983). Others propose that the Wyoming and Superior Archean cratons were originally continuous, but that the Archean crust was reworked by a later orogeny (Muehlberger et al., 1967; Van Schmus and Bickford, 1981).

The Archean Wyoming Province is truncated to the south by the Cheyenne Belt (Houston et al.,1979), a prominent fault zone, and is bordered by the Colorado Province (1700-1780 m.y. old). The Penokeon Province, a 1830-1890 m.y. old orogenic suite, truncates the Archean

Superior Province south of Lake Superior. Drill hole samples between these two early Proterozoic provinces in the buried midcontinent basement indicate a lateral continuity of these 1800 m.y. old provinces across the central midcontinent or at least the Colorado Province extends to the east (Van Schmus, 1976). The southern extent of the early Proterozoic provinces occurs along a broad transition zone from approximately southeastern Colorado across southern Nebraska and northern Kansas into central Wisconsin (Hinze and Zietz, 1985). However, the apparent northwest-trending magnetic anomalies observed in the central and southern midcontinent regions may be evidence that the early Proterozoic terranes underlie a veneer of anorogenic granites and rhyolites (Hinze and Zietz, 1985). Sims and Peterman (1986) relate these northwest-trending magnetic anomalies as part of a buried early Proterozoic orogen which they call the Central Plains orogen. According to their hypothesis, the northwest trending magnetic anomalies in Missouri and Kansas form a noticeable 'bend' in western Nebraska where a southwestern trend extends into the Front Range indicating that the uplifted early Proterozoic foldbelts exposed in Colorado and southeastern Wyoming are the western extension of the Central Plains orogen. The eastern portions of this terrane in southern Kansas and Missouri are obscured by younger, overlying anorogenic granites and rhyolites.

Apparent polar-wander curves and northwest-trending geophysical anomalies in Kansas and Missouri may indicate southwestward accretion oblique to the apparent trends to the north (Dutch,1983).

The petrology of the early Proterozoic, central midcontinent basement is characterized by a wide suite of lithologies. Schists and quartzites in Nebraska and Kansas are associated with gneissoid granitic rocks that yield dates of about 1700 m.y. ago (Bickford et al., 1981). The gneissoid granitic rocks that dominate the basement of the central midcontinent are distinguished by mild foliation caused by pervasive shearing and cataclasis. The exact timing of this event between 1480-1800 m.y. ago is uncertain because it is not known whether it correlates with one period of extensive metamorphism that reached amphibolite facies, or whether the metamorphic terrane was involved in an earlier period of regional metamorphism which affected schists and quartzites associated with the gneissoid granitic rocks (Denison et al., 1984).

After the early Proterozoic orogenic events the midcontinent region apparently stabilized and was dominated by deposition of quartz sandstones and by anorogenic activity except along the 'continental margins' to the south and east where orogenic activity continued. Besides the midcontinent of North America, major episodes of cratonization ended at approximately 1600 m.y. ago in western Australia and South Africa (Plumb and James,1986).

The anorogenic activity of the middle Proterozoic of the midcontinent can be divided into two fairly distinct terranes. The first anorgenic suite, dated between 1450-1500 m.y. ago, was the most widespread and occurred in a 500-1000 km wide belt from southern California through the central midcontinent and northeastward into Labrador (Silver et al., 1977; Anderson, 1983). In the midcontinent, this terrane, as shown in Figure 3, has been named the Eastern Granite-Rhyolite Province (Bickford et al., 1986). The most abundant magma-type generated in this terrane is the rapakivi granite (Anderson,1983). A smaller anorogenic event, dated between 1340-1400 m.y. ago (Bickford et al., 1986), occurred in a belt that extends from southeastern Kansas and western Missouri southwestward into Oklahoma, northern Texas, New Mexico, and Colorado as shown in Figure 3 (Bickford et al., 1986). This terrane has been termed the Western Granite-Rhyolite terrane (Bickford et al., 1986). The northern boundary of this terrane coincides with Yarger's (1981) boundary in Kansas between the northern mesozonal granite terrane and the southern epizonal granite terrane. Rocks in the southern or Western Granite-Rhyolite terrane are predominantly biotite-hornblende, biotite, and two-mica granites (Anderson, 1983).

The anorogenic terranes, dominated by felsic volcanics and epizonal and mesozonal felsic plutons, form the basement for much of the south and central midcontinent in an area south of southern Kansas and southern Missouri. Some of the unusual features of this middle Proterozoic terrane is the lack of sedimentary and metasedimentary rocks, a scarcity of intermediate to mafic rocks, the overall extent of this terrane, and the volume of the granite and rhyolite that compose this terrane (Van Schmus and Bickford, 1981; Anderson, 1983; Denison et al., 1984). Undeformed granitic to quartz-monzonitic plutons, which intrude into the older terranes in Nebraska, northern Kansas, and Missouri, are interpreted to be deep seated manifestations of the epizonal anorogenic granites and rhyolitic terranes to the south due to their similar compositions and granophyric textures (Van Schmus and Bickford, 1981).

The St. Francois Mountains in southeastern Missouri are some of the few good exposures of the anorogenic terrane in the midcontinent. Epizonal granites, an extensive terrane of rhyolite ash flow tuff, and small-scale rhyolitic and dacitic flows have been reported there by Sides and Bickford (1978) who interpreted the area as one or several deeply eroded calderas. U-Pb dating of rock in this area yields consistent dates of 1485 m.y. (Bickford et al.,1981). The rocks of the St. Francois Mountain

terrane are found in the subsurface of southern Missouri, southern Kansas, northern Arkansas, Oklahoma, and the Texas Panhandle region. Mesozonal granites are also found in this southern terrane along the Nemaha ridge in Kansas and in the eastern Arbuckle Mountains of Oklahoma. The mesozonal character of these granites suggests that they are a deeper seated equivalent of the epizonal granites and rhyolites of this area that have been uplifted and exposed by erosion (Denison et al., 1984).

Van Schmus and Bickford (1981) theorize that a northward-dipping plate that was being subducted at the paleocontinental margins to the east and south of Kansas may explain the volcanic rocks, granites, and the undeformed plutons of the anorogenic terrane. Magma originating from melting of the lower continental crust above the subducted plate would form plutons that would intrude into the upper crust. A recent Sm-Nd isotopic analysis of sampled midcontinent basement suggests that the 1400 m.y. old anorogenic terrane may be related to subduction in the Llano province to the south (Nelson and DePaolo, 1985). An alternative explanation for the anorogenic terranes is that it is a result of an extensional event (between 1450-1500 m.y.) which occurred after accretion of the 1650 m.y. old Central Plains Province (Bickford et al., 1986). These anorogenic terranes form a thin veneer over older crust from which

they were derived as evidenced by the ubiquitous nature of the large volumes of felsic rocks in the anorogenic terranes and by the Sm-Nd isotope data of Nelson and DePaulo (1985) which suggests remelting of older crust (Bickford et al., 1986).

After the voluminous intrusions and extrusions of the middle Proterozoic anorogenic periods the midcontinent experienced an extensional period in which the continent began to rift in a line which extends from the Great Lakes Region to central Kansas. This incipient rift has been called the Midcontinent Rift System (Wold and Hinze, 1982), and the geophysical expression of this feature is termed the Midcontinental Geophysieal Anomaly (MGA). Geophysical evidence shows that although the gravity and magnetic anomalies of the MGA are greatly attenuated south of central Kansas, these anomalies continue into Oklahoma (Yarger,1983; Lam, 1986). Geophysical data suggest that this failed rift is characterized by deep seated mafic intrusive rocks along the central axis of the rift with shallower mafic volcanic, mafic intrusive, and clastic sedimentary rocks that formed in axial rift basins and marginal basins that developed along the rift as the crust subsided (Van Schmus and Hinze, 1985).

In summary, the Precambrian geology of the United States midcontinent can be categorized as southwardly younger belts of crustal accretions to the Archean Superior

and Wyoming cratons. A very rapid and still somewhat puzzling period of crustal accretion occurred between 1600 and 1900 m.y. ago (Nelson and DePaulo, 1985). This was followed by two periods (1420-1500 m.y. and 1340-1400 m.y.) of extensive thermal activity in which felsic anorogenic plutons and extrusive rock were formed and derived from the melting of the previously accreted arc terranes (Bickford et al., 1986). Extension in the late Proterozoic (1100 m.y.) resulted in formation of the Midcontinent Rift System. Subduction along the eastern and southern midcontinent resulted in formation of the Grenville and Llano provinces respectfully.

Basement Geology of Kansas

The geology of Kansas is characterized by a thin blanket of Phanerozoic sedimentary rocks overlying the Precambrian crystalline basement. Precambrian rocks outcrop only as granitic xenoliths in peridotites in a small area of Woodson County (Bickford et al., 1971) and as basic igneous rocks (peridotitic) with inclusions of sedimentary rocks in Riley County (Jewett and Merriam, 1953).

The Precambrian basement rocks of Kansas have been divided into a northern and southern terrane (Bickford et al., 1981; Denison et al., 1984). The Precambrian rocks of northern Kansas are dominated by granitic to quartz-

monzonitic intrusives that are characterized by cataclastic to extensively sheared textures, estimated depths of emplacement between 6.5 to 13 km, and ages of emplacement of 1600-1700 m.y. (Bickford et al., 1981; Yarger, 1981; Denison et al., 1984). The basement of southern Kansas is dominated by felsic volcanic (rhyolitic) and epizonal granitic rocks which lack evidence of extensive deformation (Bickford et al., 1981; Denison et al., 1984). Rocks of this southern terrane yield ages between 1300-1400 m.y. (Bickford et al., 1981). Undeformed epizonal granitic intrusives with compositions similar to those in the southern terrane are found extensively throughout the older, deformed mesozonal granites of the northern terrane in eastern Kansas (Bickford et al.,1981; Van Schmus and Bickford, 1981). North-northeasterly trending rocks of Keweenawan age (1100 m.y.) truncate the older northern terrane. These mafic igneous rocks and flanking arkosic clastic sedimentary rocks are associated with the Midcontinent Rift System which has been interpreted as a late Precambrian aborted rift (Ocola and Meyer, 1973; Van Schmus and Hinze, 1985) that extends from the Lake Superior region into Oklahoma (Yarger, 1983; Lam, 1986).

Figure 4 shows a map of drill hole locations and lithologies of Precambrian rocks intersected by drilling in the vicinity of the study area. Drill holes are clustered over basement structure in search of hydrocarbons. Note

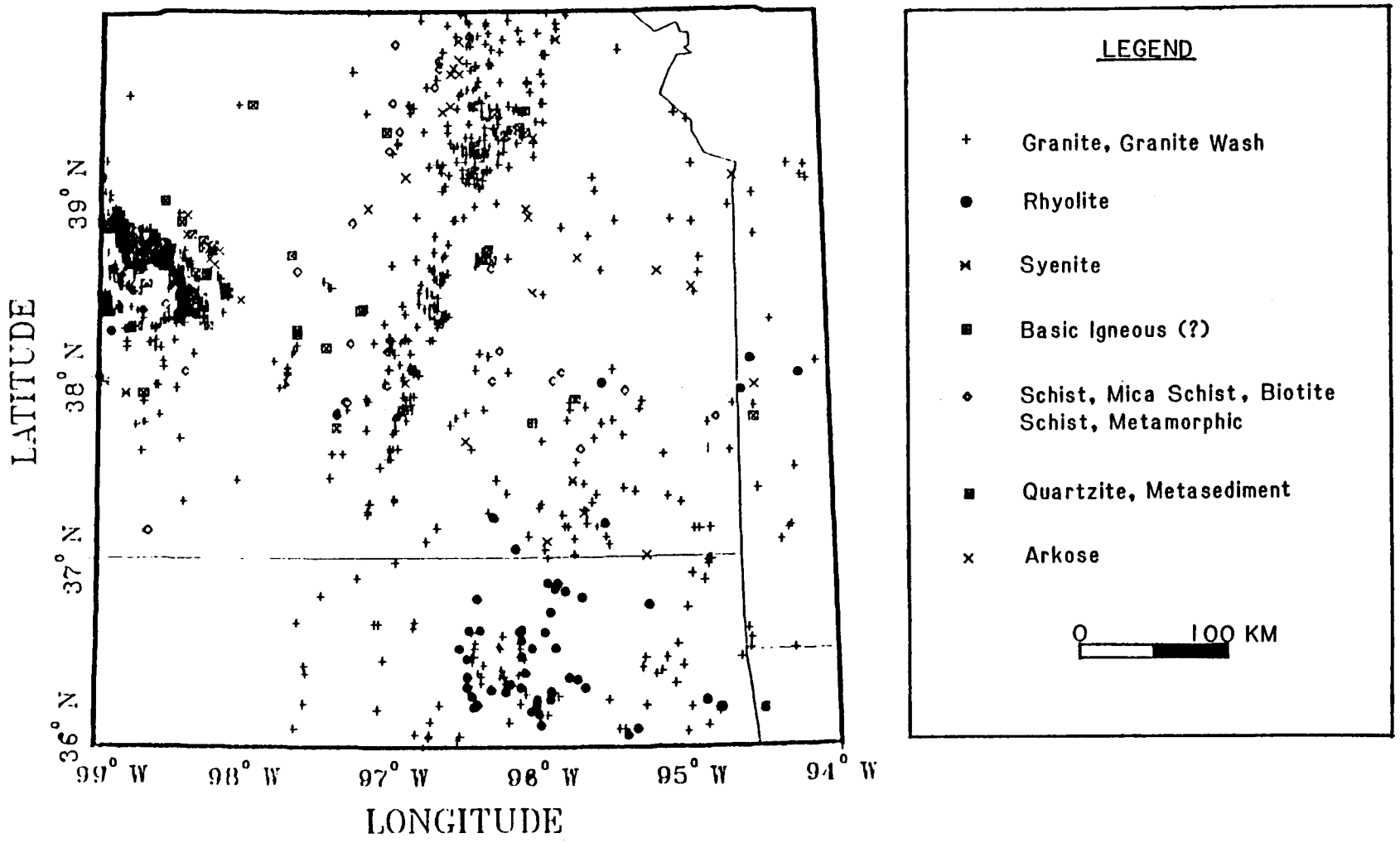

Figure 4. Map of drill hole locations and lithologies of the Precambrian basement (after Lidiak, 1986).

the predominance of rhyolites and granites in southeastern Kansas, northeastern Oklahoma, and southwestern Missouri. Drilling over the Midcontinent Rift System has encountered arkoses, granites, quartzites, and some mafic rocks. Metamorphic rocks are almost exclusively found in the northern terrane and are found in an east-west trending band across southeastern Kansas.

The configuration of the Kansas basement has been relatively unchanged since the late Paleozoic Era (Yarger, 1983). The Nemaha ridge, a major north-northeasterly trending feature in eastern Kansas, is faulted on its eastern edge by the Humboldt fault (Figure 5). A structural contour map of the Precambrian basement surface was made using information from drill hole data (Figure 6). This map shows the trend of the Nemaha ridge and the Humboldt fault as well as the major basins and arches of eastern Kansas. In southeastern Kansas, the Nemaha ridge separates the Sedgewick basin from the Cherokee basin, and the Bourbon arch separates the Cherokee basin from the Forest City basin (Figure 5 and 6).

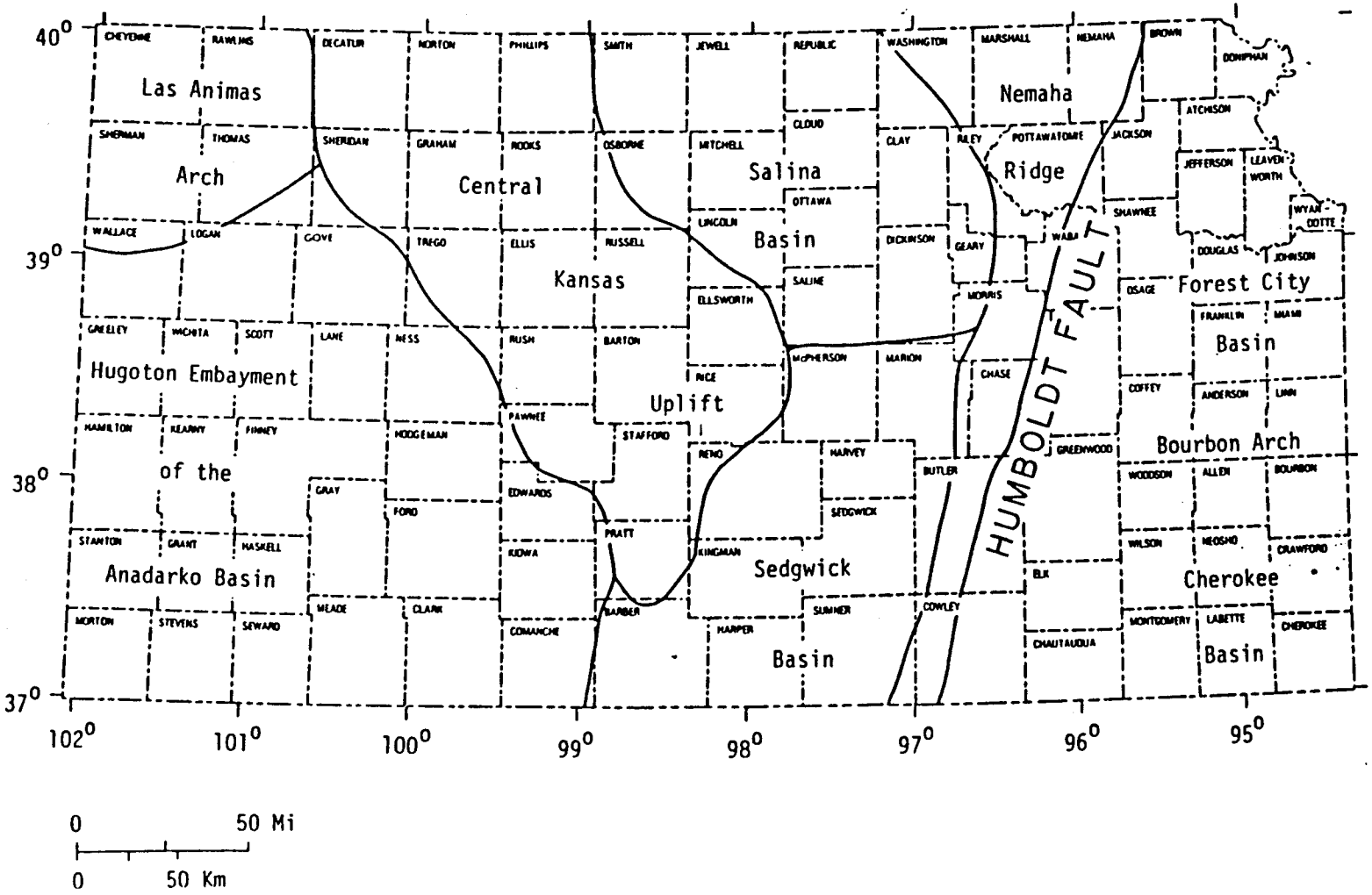

Figure 5. Map of major basement features in Kansas (after Yarger, 1983).

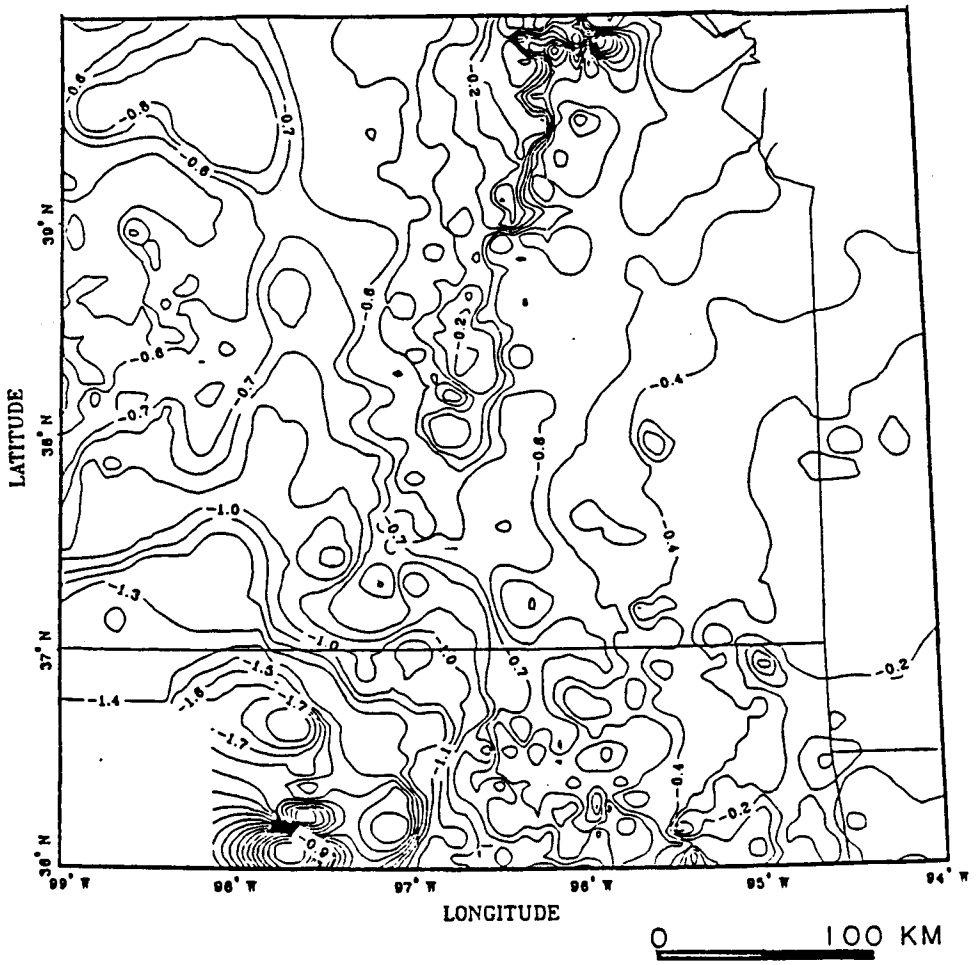

Figure 6. Precambrian basement surface map of southeastern Kansas, western Missouri, northeastern Oklahoma, and northwestern Arkansas derived from drill hole information compiled by (after Lidiak, 1986). Contour interval is 0.1 km relative to sea level.

III. GEOPHYSICAL SETTING

Much of the buried Precambrian basement geology discussed in the previous chapter was interpolated and interpreted across the midcontinent with magnetic and gravity data. Results from seismic crustal studies confirms the variability of the crust in the midcontinent.

This section will first investigate the large-scale geophysical setting of the midcontinent region. The area of investigation will then be tied into the regional picture so that the geophysics of the study area can be fit into the larger scheme.

Regional Magnetic Data

A portion of the composite magnetic anomaly map of the United States is shown in Figure 7. Dark shades indicate magnetic highs, while lighter shades represent magnetic lows. A linear series of magnetic lows between broad magnetic highs to the south and lows to the north parallels the Kansas-Oklahoma border in southern Kansas. The Wichita Magnetic Low is located within the prominent white area in southeastern Kansas (Figure 7) and occurs along this major lineament between the magnetic terranes.

Figure 7. Composite magnetic anomaly map of the south central midcontinent (after Hinze and Zietz, 1985). Contour interval is 200 gammas.

Other basement terranes or features that are discernable on the composite magnetic anomaly map are the, the west-northwesterly striking highs of the Southern Oklahoma aulacogen in southern Oklahoma and northern Texas, and the northeast-striking highs and flanking magnetic lows related to the Midcontinent Rift System. A prominent magnetic high extends from western Arkansas to Colorado and south into eastern New Mexico and northwestern Texas, and corresponds to the Western Granite-Rhyolite Province (Eickford et al., 1986).

The 2° averaged MAGSAT scalar magnetic field map (Starich, 1984) over the midcontinent region of the United States is shown in Figure 8. The data were recorded at a mean flight elevation of 400 km. Von Frese et al., (1982) demonstrated that MAGSAT data is useful in mapping crustal magnetic anomalies. Frey (1982) suggests that MAGSAT scalar anomalies reflect boundaries of major tectonic terranes in Asia. He also states that suture zones should produce magnetic anomalies since these lineaments juxtapose crustal blocks of contrasting susceptibilities, varying crustal thicknesses, and possibly different depths to the Curie isotherm. A large magnetic high, the South-Central United States Magnetic Anomaly (SCUSMA), extends from west-central Texas across Oklahoma into the Great Lakes region (Starich, 1984). A steep gradient, separating the positive anomaly to the south from a negative anomaly

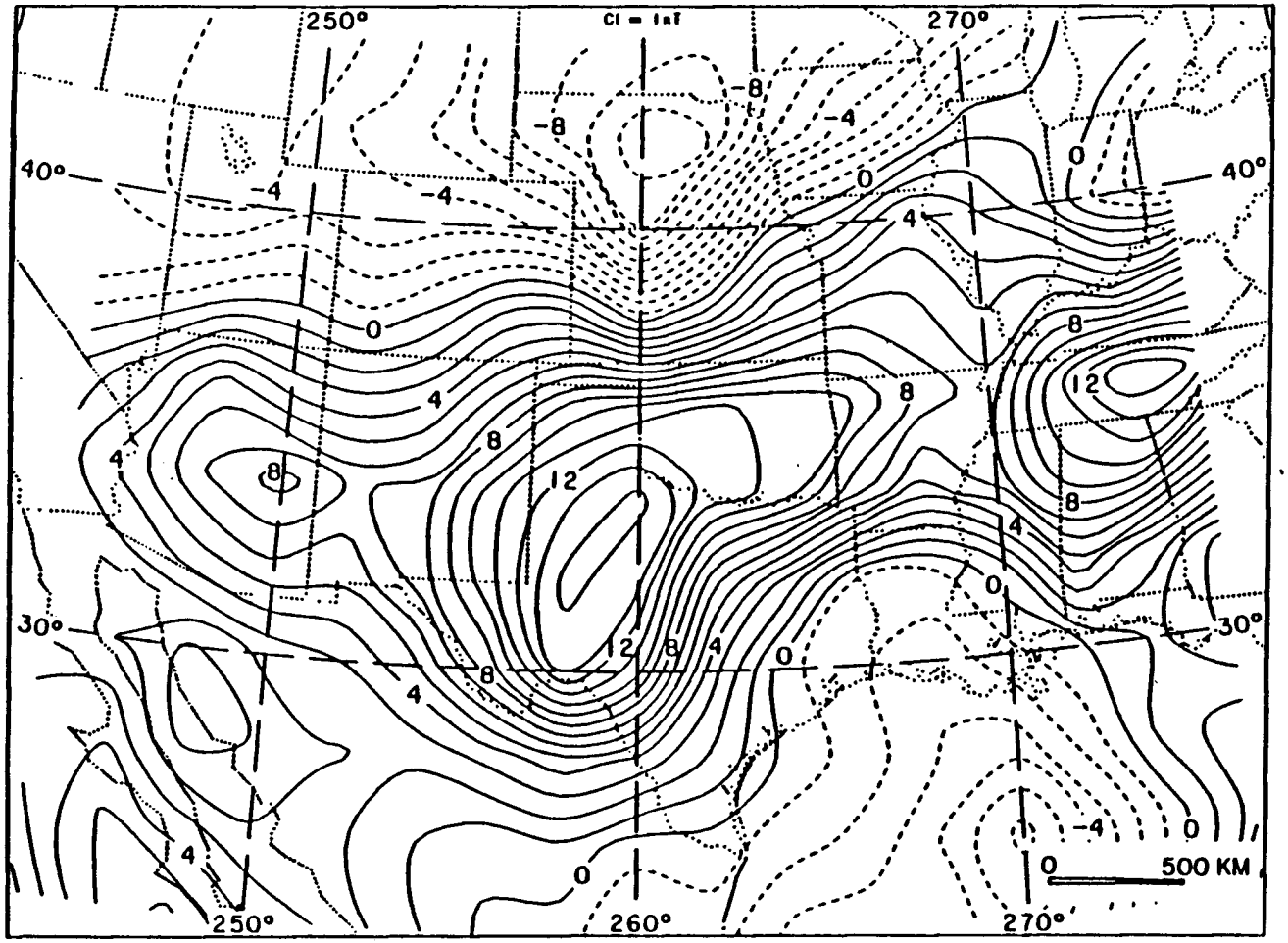

Figure 8. 2° averaged MAGSAT scalar magnetic field map over the midcontinent (after Starich, 1984). Contour interval is 1 gamma.

situated over Nebraska, occurs on the northern margin of the SCUSMA in northernmost Oklahoma and across Kansas.

Regional Gravity Data

Figure 9 is the Bouguer gravity anomaly map, that was separated from a data set compiled by the U.S. Geological Survey and the Society of Exploration Geophysicists (1982). The Bouguer gravity anomalies show effects of lateral density variations below sea level, because the effects of mass above the datum level (sea level) have been removed. Isostatic effects, which are related to compensation of topography by variations in subsurface masses, complicate interpretation of the Bouguer gravity anomaly map. A good example of isostatic effects is illustrated over the Rockies in the western portion of Figure 9 (Salleh, 1984).

A northeast-trending positive gravity anomaly extending from central Kansas into northwestern Iowa correlates with the Midcontinent Rift System. A large negative gravity anomaly in western Missouri and eastern Kansas may relate to the 1800-1900 m.y. old Central Plains Province as shown in Figure 9. A positive gravity anomaly occurs to the south of this negative anomaly and in a region designated by Bickford et al. (1986) as the Western Granite-Rhyolite terrane. The west-dipping gradient in western Kansas is related to thickening of the crust and

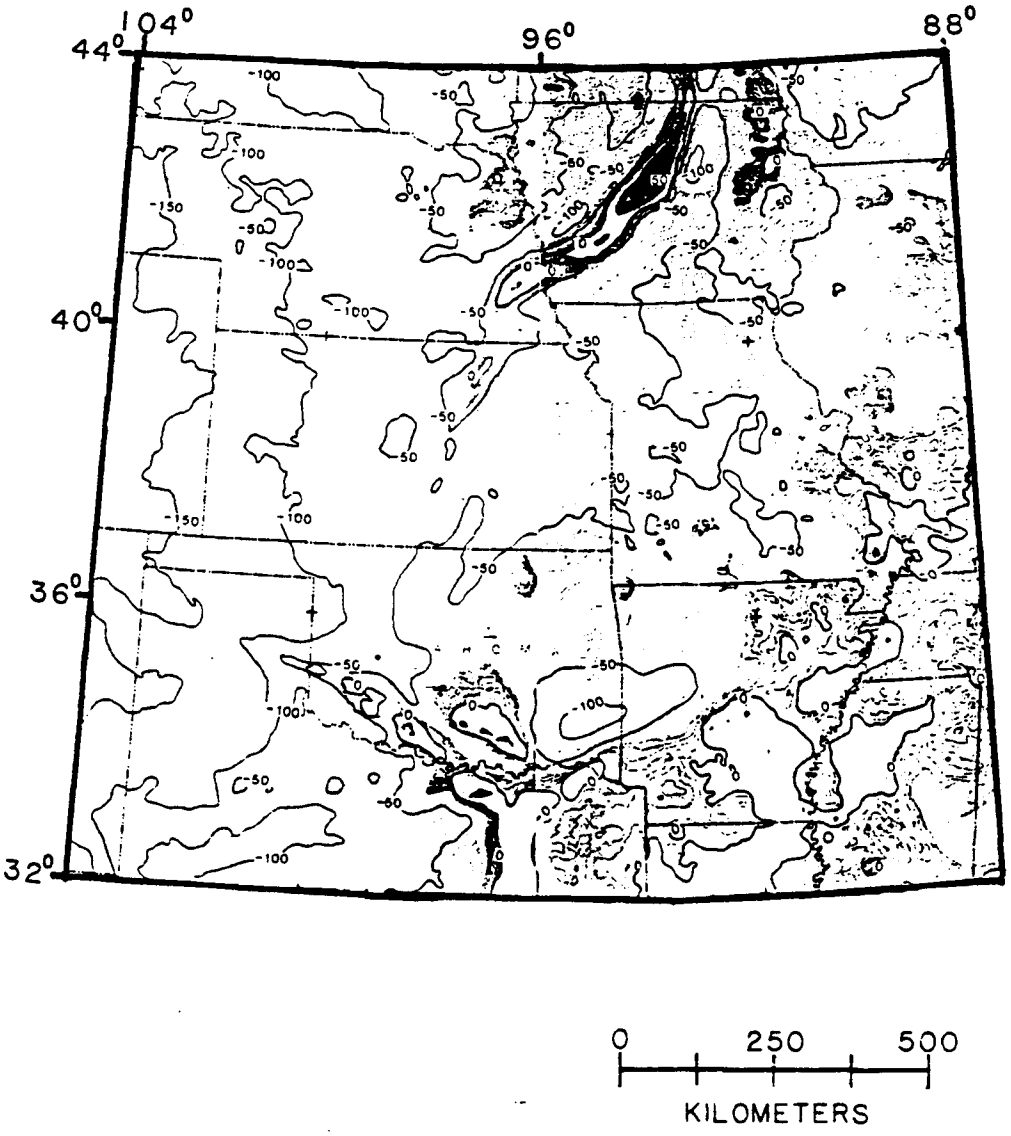

Figure 9. Bouguer gravity anomaly map of the midcontinent (after Society of Exploration Geophysicists, 1982). Heavy contour interval is 50 mGals.

the sedimentary rock cover to the west (Lam and Yarger, 1986;Lam, 1986). The most important cause of this gradient is crustal thickening (Lam, 1986).

Magnetic Studies in Kansas

Prior to the statewide aeromagnetic survey of Kansas, comprehensive early magnetic studies of the Precambrian basement rocks in Kansas were restricted to mainly profile studies. Hambleton and Merriam (1959) interpreted magnetic lows to be a result of structural basement highs and the combined effects of basement and sedimentary rocks in northern Wilson County, Kansas. Farquhar (1957) suggested that magnetic lows in Kansas could be caused by the lower susceptibilities of granites with respect to metamorphic host rock. Heiland (1929) cites susceptibility contrasts between basement lithologies of granite and schist in Butler County, Kansas (along the flanks of the Wichita Magnetic Low) as a cause of a local magnetic low. Woollard (1943) reported that the magnetic signature over the Nemaha ridge in eastern Kansas is not correlative with the basement structure, but the magnetic character is a reflection of basement lithological variations.

Recently an aeromagnetic survey over the state of Kansas has yielded important information concerning the basement geology of Kansas. Yarger (1981,1983,1985) has

summarized the details of the surveying, processing techniques, and interpretation of these data.

Since the Phanerozoic sedimentary rock layers may be considered essentially non-magnetic, the total intensity aeromagnetic map of Kansas (Figure 10) yields a great deal of information concerning the sediment-blanketed Precambrian basement in this area. On a broad view, the northwest magnetic trends are truncated by a northeast trend in northcentral Kansas. This northeast trend of linear magnetic highs and flanking magnetic lows are interpreted to be an expression of a Precambrian failed rift and related sedimentary rocks. Gabbroic and basaltic rocks of Keweenawan age result in positive anomalies while negative anomalies are generally associated with thick clastic and felsic rocks (Yarger, 1981). The magnetic anomalies correlated with the Midcontinent Rift System appear to terminate against an east-west trending negative magnetic lineament. This linear magnetic feature can be traced from eastern Colorado into western Missouri (Yarger, 1981). To the east of the termination of the Midcontinent Rift System in southeastern Kansas the character of this magnetic low changes as it becomes much wider, has a greater negative amplitude, and has higher wavenumber, oval-shaped lows with encircling highs superimposed within it (Figure 10). This prominent area of magnetic lows is centered over the city of Wichita, Kansas, and therefore

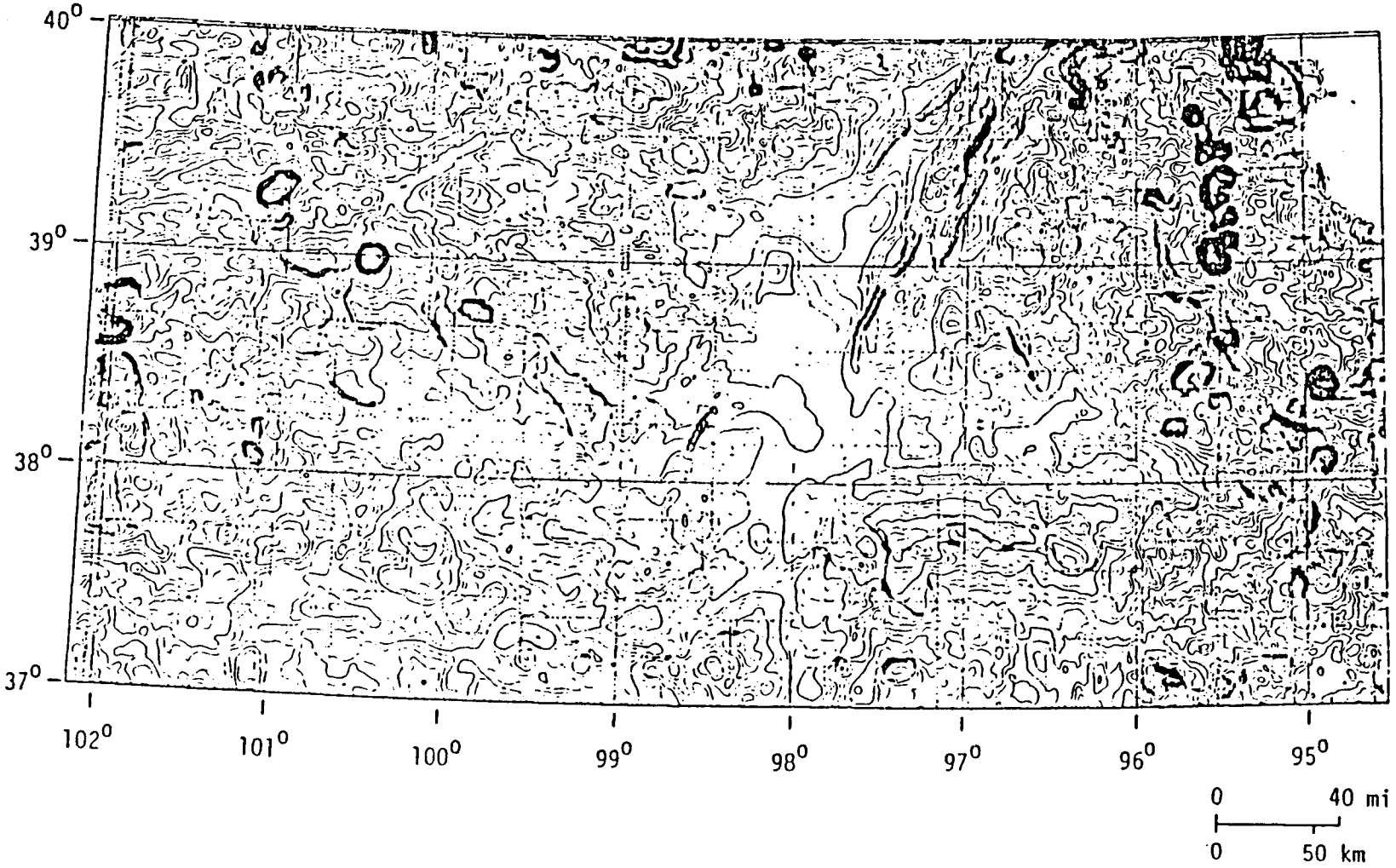

Figure 10. Total intensity aeromagnetic map of Kansas (after Yarger et al., 1985). Contour interval is 50 gammas.

Yarger (1983) named this negative anomaly the Wichita Magnetic Low. Using spectral filtering techniques Yarger (1983,1985) illustrates that the southern edge of this negative, linear anomaly forms a fairly distinct boundary and interprets this southern margin as an area of contrasting rock types. He further postulates that this boundary may be 1) a paleoplate boundary (suture) between the northern and southern terrane, 2) a subsided granitic slab overlain by a sedimentary or metasedimentary wedge, or 3) non-magnetic granitic basement.

Gay (1984) mapped basement plutons in the Wichita Magnetic Low based on the criterion of characteristic magnetic signatures of magnetic lows surrounded by magnetic highs (Figure 2). A core from a drill hole sample in the western part of the Wichita Magnetic Low yielded an age of 1380 m.y. Gay (1984) also noted the similarity of the magnetic signature of the plutons within the Wichita Magnetic Low and those in the St. Francois Mountains region of southeastern Missouri. These magnetic lows in southeastern Missouri are associated with quartz-feldspar granites with few mafics that Kisvarsanyi (1981) termed the Graniteville-type granite. The characteristic magnetic signature of Graniteville-type intrusives is a featureless central magnetic low surrounded partially or fully by a encircling high (Kisvarsanyi, 1981; Gay, 1984).

Kisvarsanyi (1981) analyzed cores associated with Graniteville-type granites and concluded that these rocks are two-mica or tin-granites. Tin-granites or two-mica granites have very little magnetite associated with them since the majority of the iron content is taken up by biotite (Bash, 1984). Thus the magnetic lows over the Graniteville-type plutons reflect the lack of magnetite in these granites as compared to the host rock.

Gay (1984) suggests that the ringing highs around the featureless lows may be due to mineralization around the plutons related to precipitation of magnetite by hydrothermal solutions, an example of this is the Idaho batholith in southern Idaho (Criss and Champion, 1984), and magnetization effects such as the effects of the inclination of the earth's magnetic field and/or a component of remanent magnetization. Gay (1984) further postulates that the inconsistent patterns of the ringing highs may reflect differences in petrology, permeability, and structure of the country rock surrounding the Graniteville-type plutons.

Another significant feature in the total intensity map of Kansas is a discontinuous series of high-amplitude, steep gradient, circular magnetic highs that extend from northeastern Kansas south into east-central Kansas where these highs seemingly terminate or are attenuated at approximately the eastern end of the Wichita Magnetic Low

(Figure 10). Basement corresponding to two of these prominent positive anomalies in northeastern Kansas were sampled by drilling. The results of analyses from these cores yield U-Pb zircon ages of 1350 m.y., petrologies of epizonal granites related to those of the southern terrane of Kansas, and magnetite contents of 2% by weight (Steeples and Bickford, 1981). Other magnetic anomalies with magnetic signatures similar to those sampled have been interpreted as epizonal granites. Figure 11 is an interpretation of Precambrian terranes inferred from the total intensity magnetic maps of Kansas and isotopic determined ages.

Gravity Studies in Kansas

An early gravity study of the Precambrian basement by Woollard (1959) demonstrated that the largest gravity anomaly one could expect from basement structure in Kansas (such as the Nemaha ridge-Humboldt fault) is less than one milliGal, because the basement is capped almost exclusively by limestone that has densities nearly identical to the underlying basement. He concluded that large residual anomalies must be related to density contrasts within the basement.

A Bouguer gravity anomaly map of Kansas, compiled from the statewide data set of the Kansas Geological Survey, is

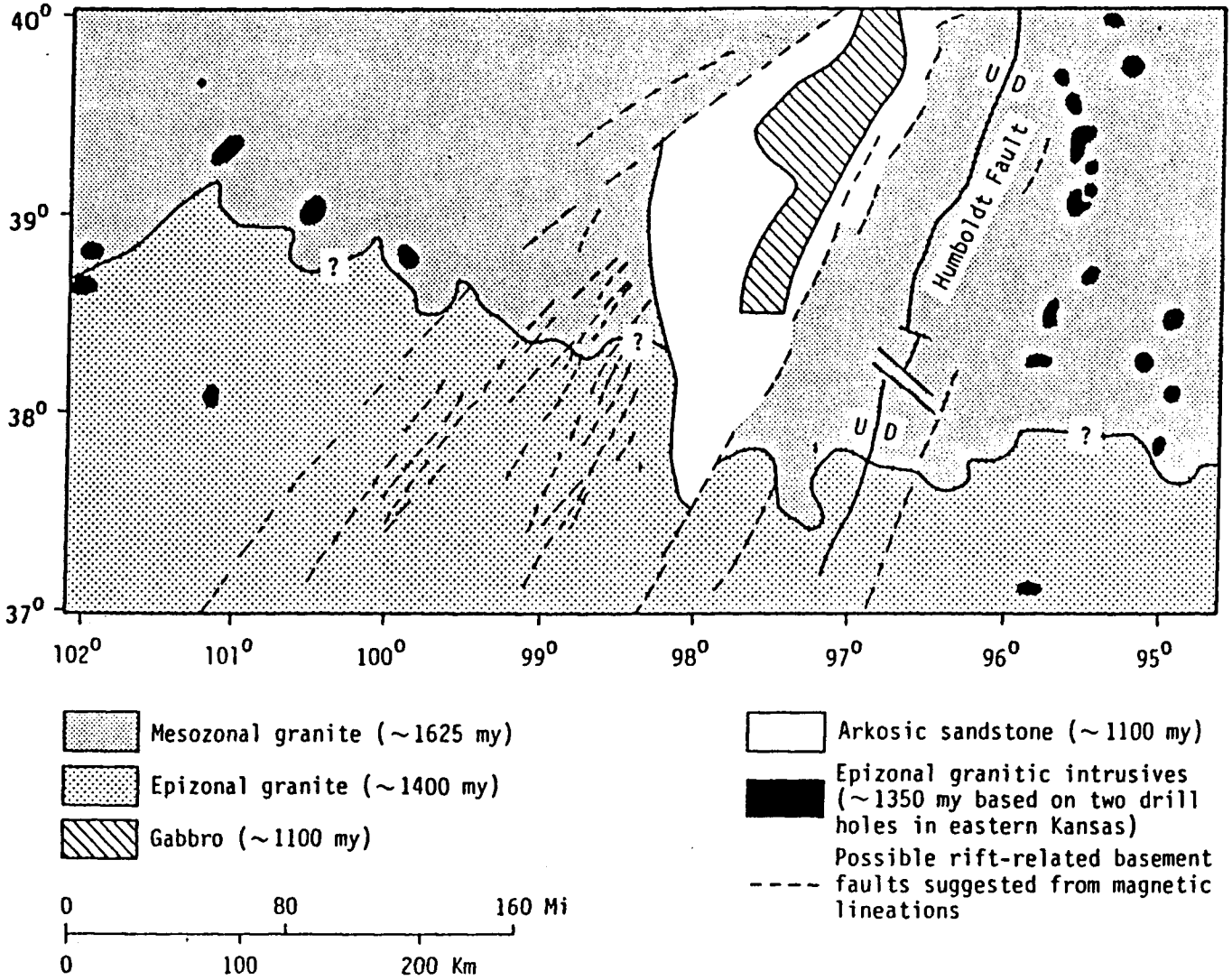

Figure 11. Interpretation of Precambrian terranes in Kansas (after Yarger, 1983).

shown in Figure 12. Detailed information concerning the gravity surveying, processing, and corrections are available in Lam and Yarger (1986) and Lam (1986).

Prominent features of the gravity map (Figure 12) are a steep, west-dipping gravity gradient in western Kansas reflecting crustal thickening to the west, a northeast trending gravity high with flanking lows in north-central Kansas relating to the Midcontinent Rift System, a long wavelength gravity high in the southeastern corner of Kansas that occurs over a rhyolitic basement, and a broad gravity high near the southeastern end of the Central Kansas Uplift (Lam, 1986).

Lam (1986) recently completed a regional interpretation of the Bouguer gravity map of Kansas. A summary of his findings is as follows. Yarger's (1981) suggestion that the Midcontinent Geophysical Anomaly (MGA) may extend at least to the Kansas-Oklahoma border is supported by analysis of the gravity data. Lam (1986) speculates that the abrupt attenuation of the amplitude of the MGA from central Kansas across the proposed suture boundary (Yarger,1981) into southern Kansas is a reflection of a change in the physical properties of the crust from a brittle, cooler, northern terrane to a more ductile, hotter, southern terrane at the time of the initial rifting event. The higher geothermal gradient over the southern terrane was related to anorogenic activity prior to

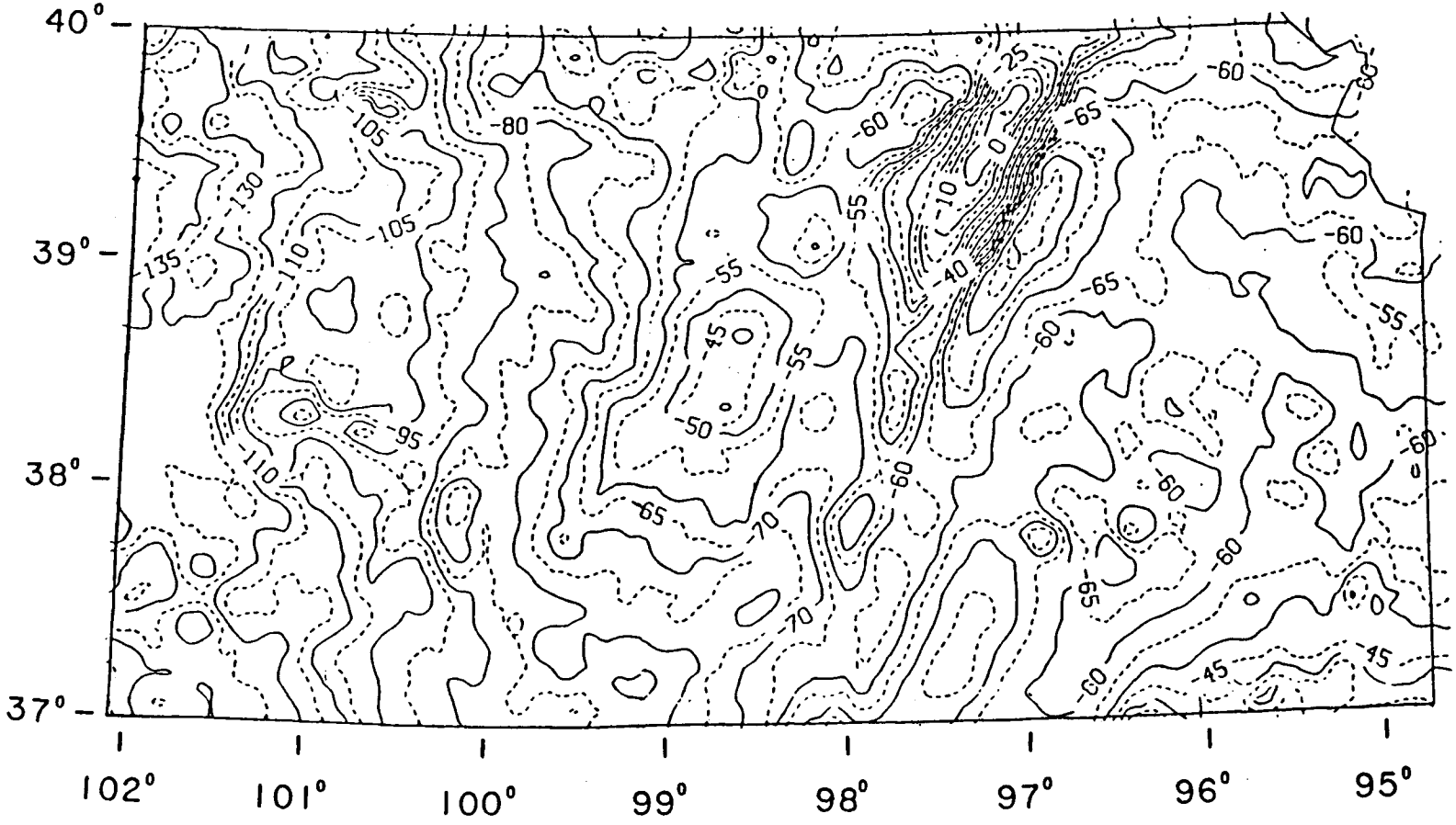

Figure 12. Bouguer gravity anomaly map of Kansas. Contour interval is 5 mGals.

rifting. An interpretation of the gravity data suggests that the long wavelength component of the Wichita Magnetic Low maybe related to a non-magnetic granitic body at mid-crustal depth, while the short wavelength component is correlated to reversely magnetized mafic intrusives near the basement surface. Lam (1986) also suggests that the broad gravity anomalies in southeastern Kansas are caused by intrusions below the veneer of anorogenic granites and rhyolites in this basement terrane.

Seismic Crustal Studies

Seismic studies in the vicinity of the study area give clues to the crustal structure. The results from seismic refraction and reflection surveys are important to constrain the potential field models. Figure 13 shows the location of the refraction and reflection surveys in relation to the area of investigation. In this discussion the velocities referenced are for compressional waves.

Steeples (1976) interpreted a U. S. Geological Survey refraction profile in eastern Colorado and northcentral Kansas. His results suggest a 4.5 km/s layer to about 1.3 km depth, a 6.0 km/s layer from 1.3 km to 8.1 km depth, and a 6.1 km/s layer from 8.1 km depth to the Moho. This model shows a west-dipping Moho at 38 km depth in north-central Kansas increasing to 44 km depth in eastern Colorado. An

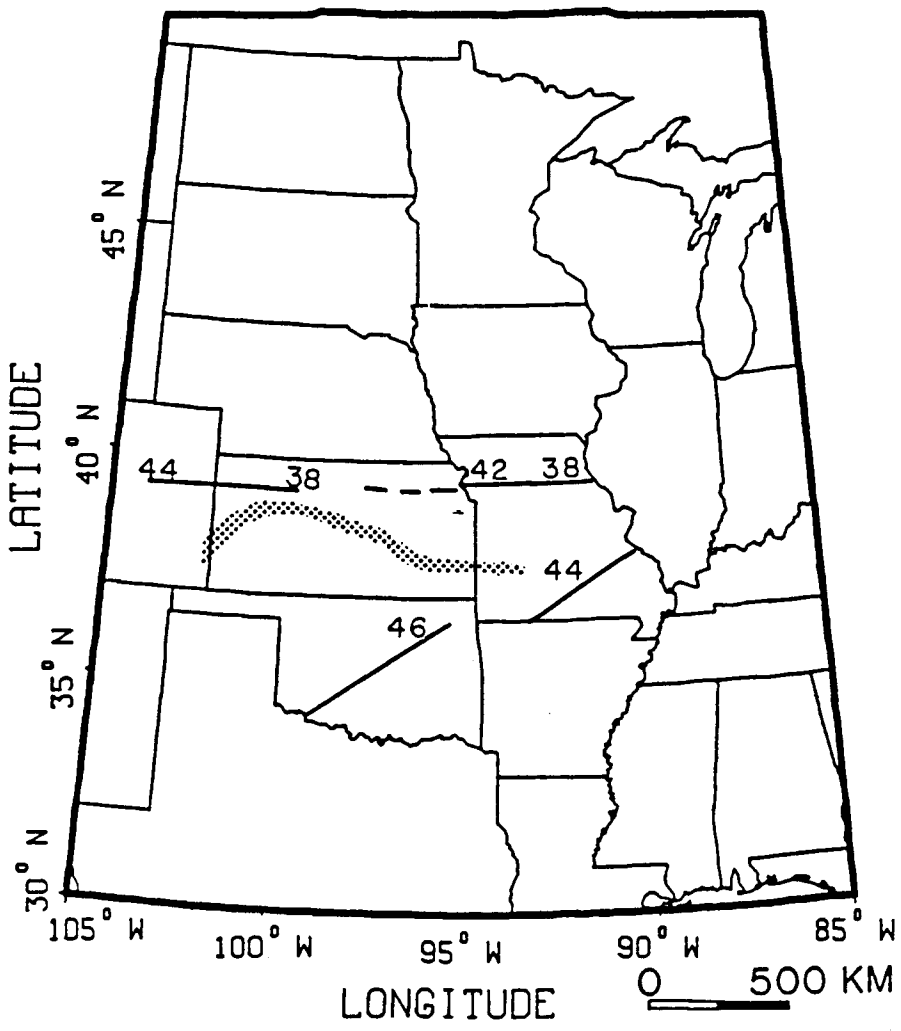

Figure 13. Map of crustal refraction (solid) and reflection profiles (dashed) in the study area. Numbers represent calculated depths to Moho in kilometers. Dotted area is the approximate location of Yarger's proposed suture zone (1981).

upper mantle velocity of 8.25 km/s was observed on this line (Steeples, 1976).

An investigation of a reversed profile in Oklahoma by Mitchell and Landisman (1970) yields a crustal model in which the upper crust is approximately 16 km thick and is underlain by a thin low velocity zone that thickens to the southwest. They interpret the Moho at approximately 46 km depth and an upper mantle velocity (Pn) of 8.2 km/s.

Stewart (1968) interpreted two reversed refraction profiles in northern and southern Missouri. The interpretation of the northern line indicates a crust composed of an 8 km thick, 6.1 km/s upper layer underlain by a 6.2 km/s layer to 20 km depth, and a 6.6 km/s layer between 20-40 km depth. An upper mantle (Pn) velocity of 8.0 km/s is suggested. All of the crustal layers dip to the west so that the crustal thickness is approximately 38 km in northeastern Missouri and 42 km in northwestern Missouri. Results of the southern profile were difficult to interpret since the crust in this area seems to be laterally inhomogenous and could not be approximated by assuming uniform layers of varying dip. However, Stewart (1968) suggests a 44 km thick crust with a Pn velocity of 8.1 km/s.

Miller (1980) interpreted Pn residuals from earthquake events in order to characterize the crust over various earthquake monitoring stations in eastern Kansas (Figure

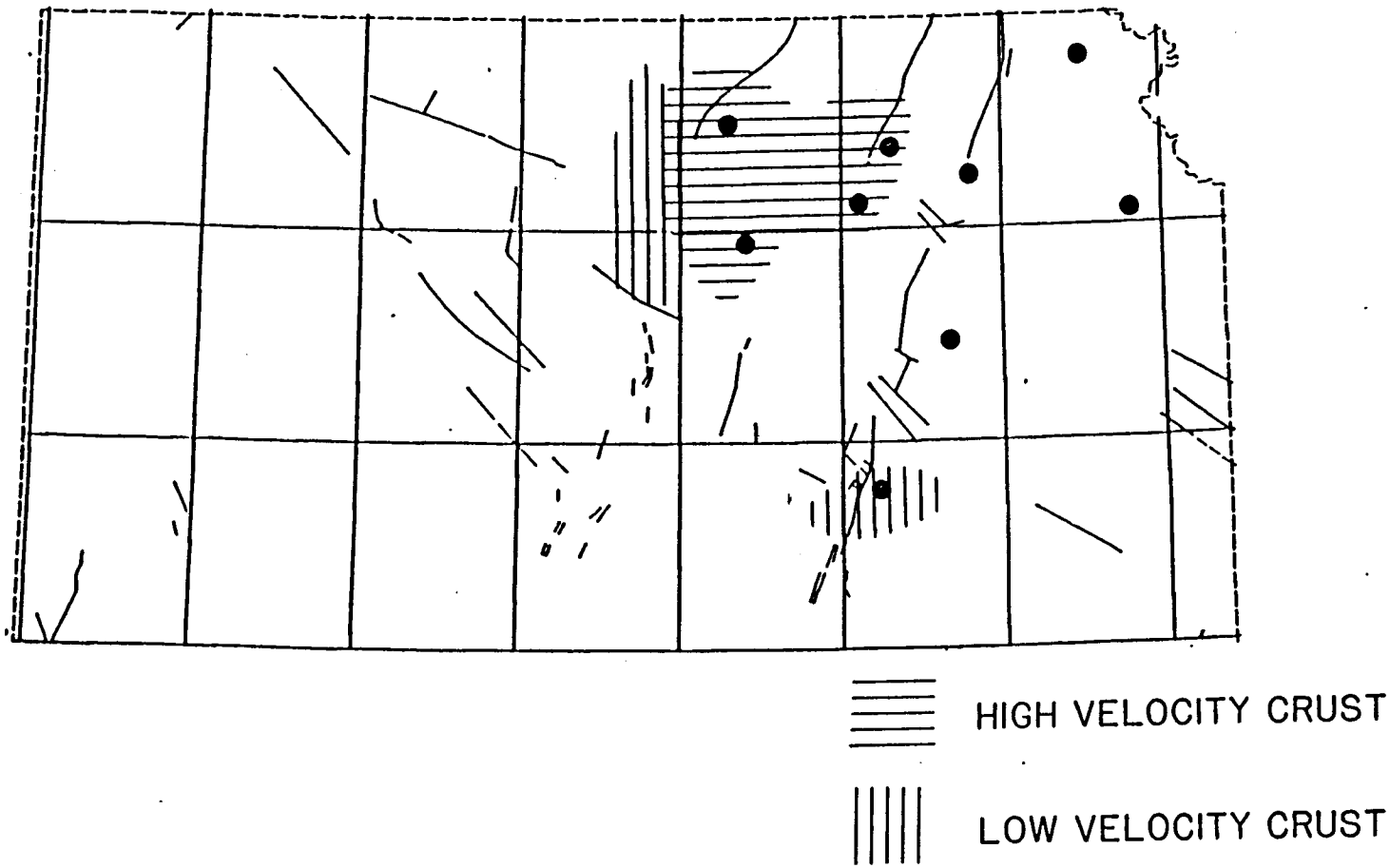

Figure 14. Map of Kansas showing station locations (●) and interpretation of Pn residuals from earthquake events (modified after Miller, 1980).

14). His interpretations (Figure 14) are that high velocity crust occurs over the Midcontinent Rift System in northcentral Kansas which is related to mafic rocks in the crust. A low velocity crust occurs west of this area and may be a result of thick clastic sediments (Rice Formation) that flank the failed rift. A conspicuous low velocity anomalous crust, located over the Wichita Magnetic Low, is interpreted to be related to the suture zone proposed by Yarger (1981).

Serpa et al. (1984) outlined the results of a COCORP reflection survey in northeastern Kansas (Figure 13). A prominent boundary separating a shallow transparent zone from underlying reflections and diffractions occurs at approximately 5s (approximately 15 km). The shallow transparent zone is interpreted by Brown et al. (1983) as diffractions and layering related to mafic intrusions, gneissic banding, or possibly metasedimentary rocks emplaced by large-scale overthrusting (subduction?). The interpreted depth to the Moho of approximately 36 km is speculative, because it is based on an apparent decrease in the density and number of reflected events and not on a continuous reflector.

Braile et al. (1984) have compiled the results of seismic refraction profiles across the conterminous United States. The average crustal velocity (Vp) was derived from these refraction profiles and plotted on a map projection

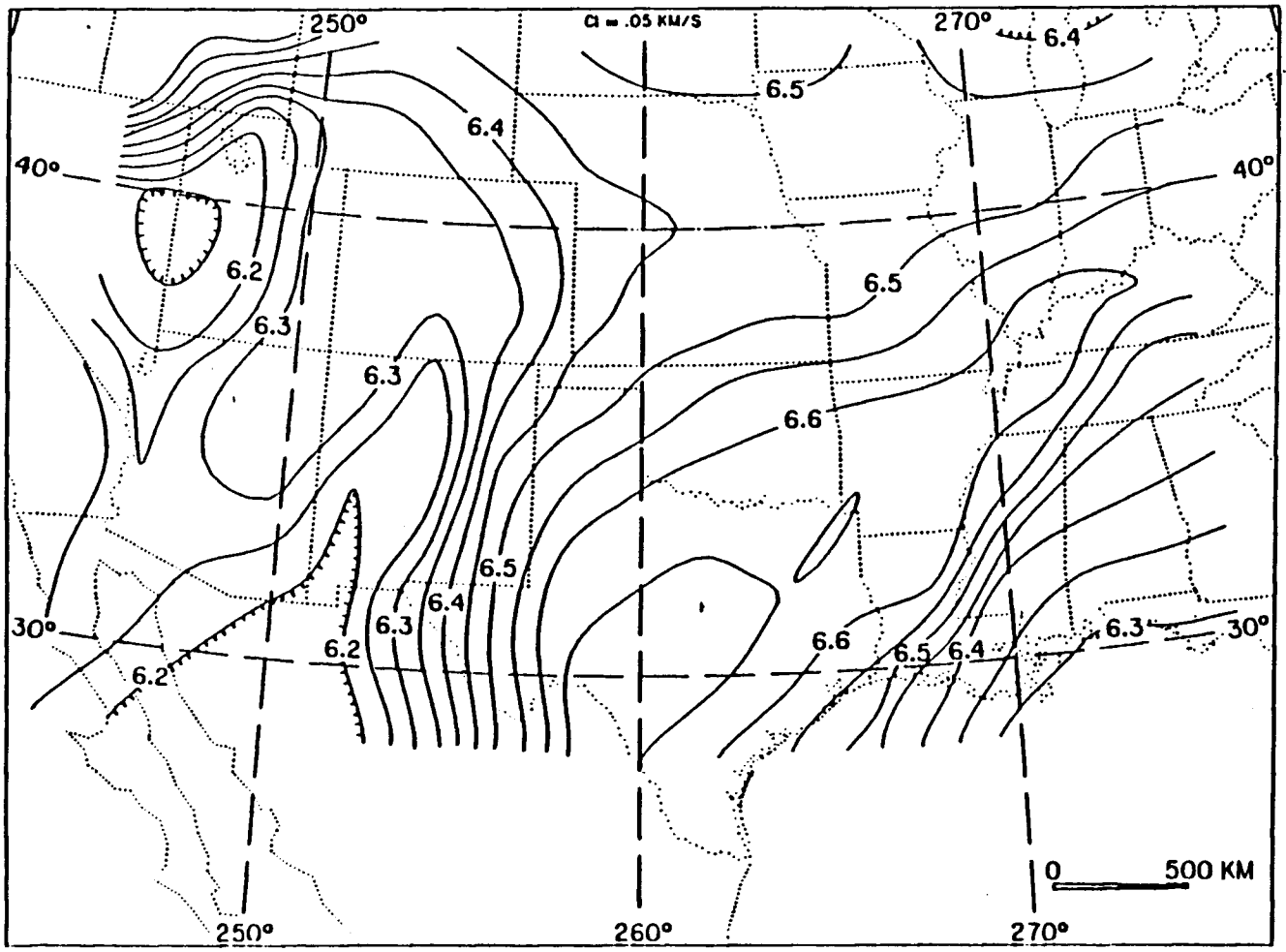

Figure 15. Average crustal velocity map of the United States compiled from refraction profile data (after Braile et al., 1984). Contour interval is 0.1 km/s.

of the United States. Figure 15 shows the average crustal velocity map of the United States. The average crustal velocity is defined as:

$$Vp=[\sum h_i / \sum(h_i/v_i)]$$

where, h_i=crustal thickness of the i^{th} layer

v_i=velocity of the ith layer (excluding the surface sedimentary layers).

The average crustal velocity may be used to relate crustal structure and crustal growth (Smithson et al.,1981). The most important feature of this map with respect to this investigation is the Vp gradient that subparallels the Kansas-Oklahoma border, separating lower average crustal velocities to the north from higher average crustal velocities to the south.

IV. THE MAGNETIC AND GRAVITY ANOMALY MAPS

Total intensity aeromagnetic and Bouguer gravity data sets of Kansas were obtained from the Kansas Geological Survey. The aeromagnetic data set was recorded at a fixed barometric elevation of 0.76 km, an east-west flight line spacing of approximately 3.2 km, and a north-south tie line spacing of approximately 32 km (Yarger, 1983). A more detailed account of the aeromagnetic survey, the data acquisition, and the data reduction are available in Yarger (1983). The Bouguer gravity anomaly data set in southeastern Kansas was measured at approximately 6.4 km north-south intervals and 1.6 km east-west intervals (Lam and Yarger, 1986). Lam and Yarger (1986) and Lam (1986) describe the field procedures and data reduction used in preparing this data set.

The two data sets were gridded in order to facilitate the isolation, enhancement, and modeling techniques. The magnetic data set was gridded using 3.2 x 3.2 km grids, while the gravity data set was gridded at 4.1 x 4.1 km grids. The gridded data sets were then plotted (Figures 16 and 17) and compared visually with Kansas Geological Survey maps over the same area (Yarger et al., 1980; Yarger et

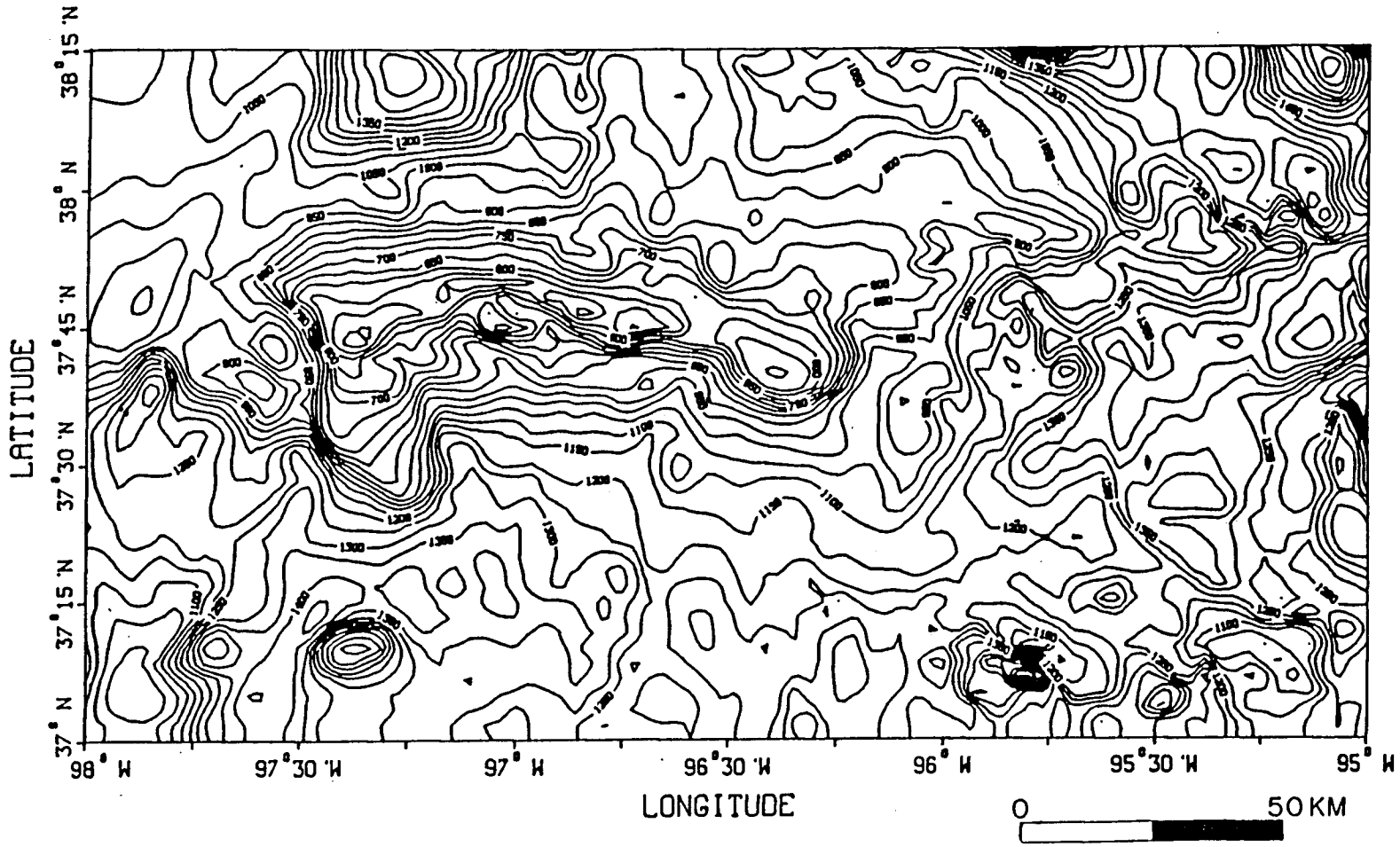

Figure 16. Total intensity magnetic map of southeastern Kansas. Contour interval is 50 gammas.

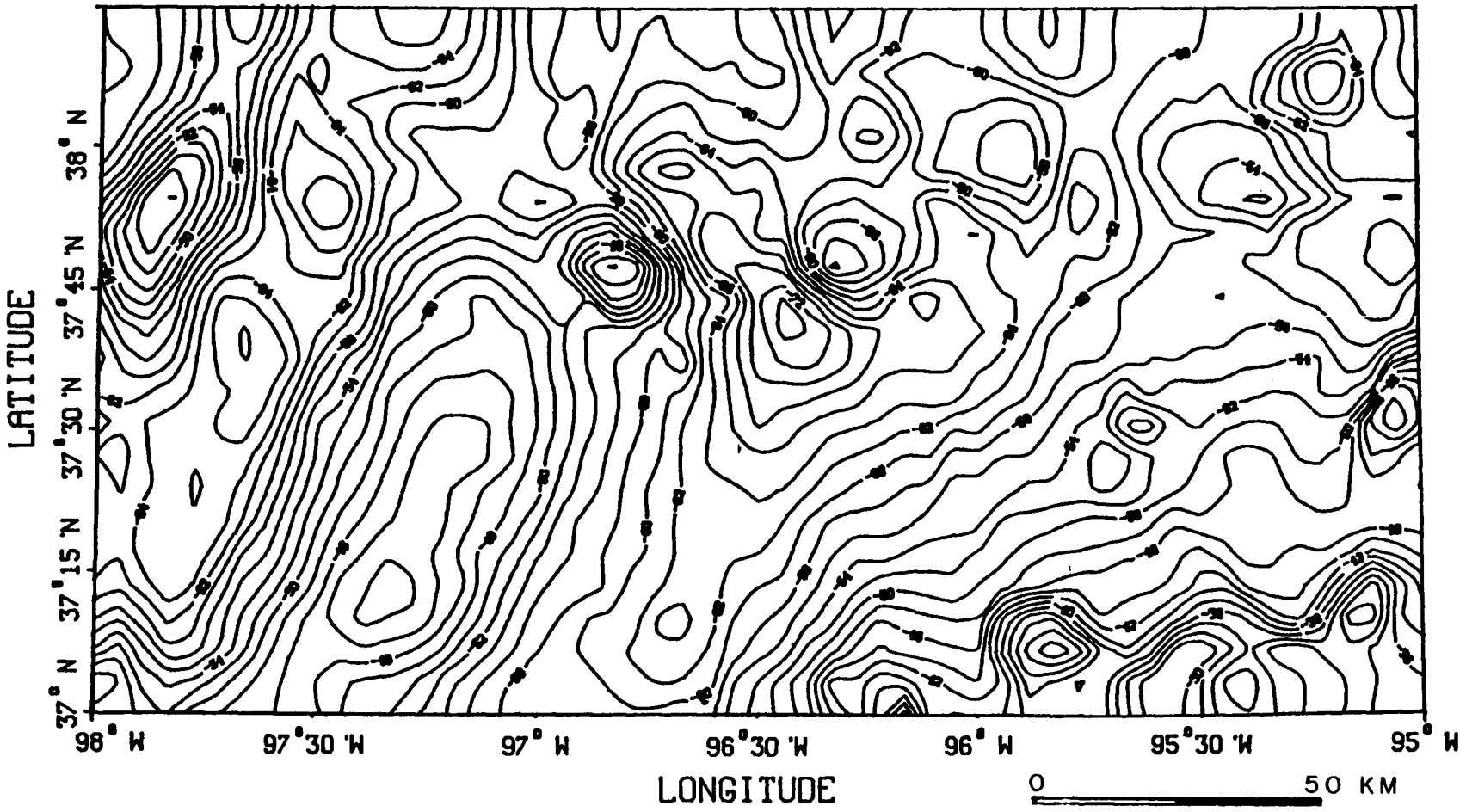

Figure 17. Bouguer gravity map of southeastern Kansas. Contour interval is 2 mGals.

al., 1985). Plots of the regridded data sets are nearly identical to those of the published maps.

In order to make a visual analysis and interpretation of the maps, a variety of isolation and enhancement techniques were applied. The techniques used on both data sets include upward continuation and vertical derivative wavenumber filtering. In addition the magnetic data set was reduced-to-the-pole before applying the upward continuation and vertical derivative filters. The residual magnetic field was also isolated by the intersecting-profile method. The isolated and enhanced features present in the data sets are used as aids in interpreting the maps and constraining the modeling.

The magnetic data were reduced-to-the-pole before applying filters. The reduction-to-the-pole technique is useful because it removes the effects due to the inclination and declination of the earth's magnetic field. Reduction-to-the-pole shifts the anomalies to their proper positions above the causative bodies and thus improves the comparison of the magnetic and gravity anomalies. This technique assumes that the effect of remanent magnetization is negligible which is generally valid in Precambrian rocks of the midcontinent (Hinze and Zietz, 1985).

The reduced-to-the-pole map in Figure 18 was produced assuming an inclination of 68° and a declination of 0° W. Comparison of the reduced-to-the-pole map (Figure 18) with

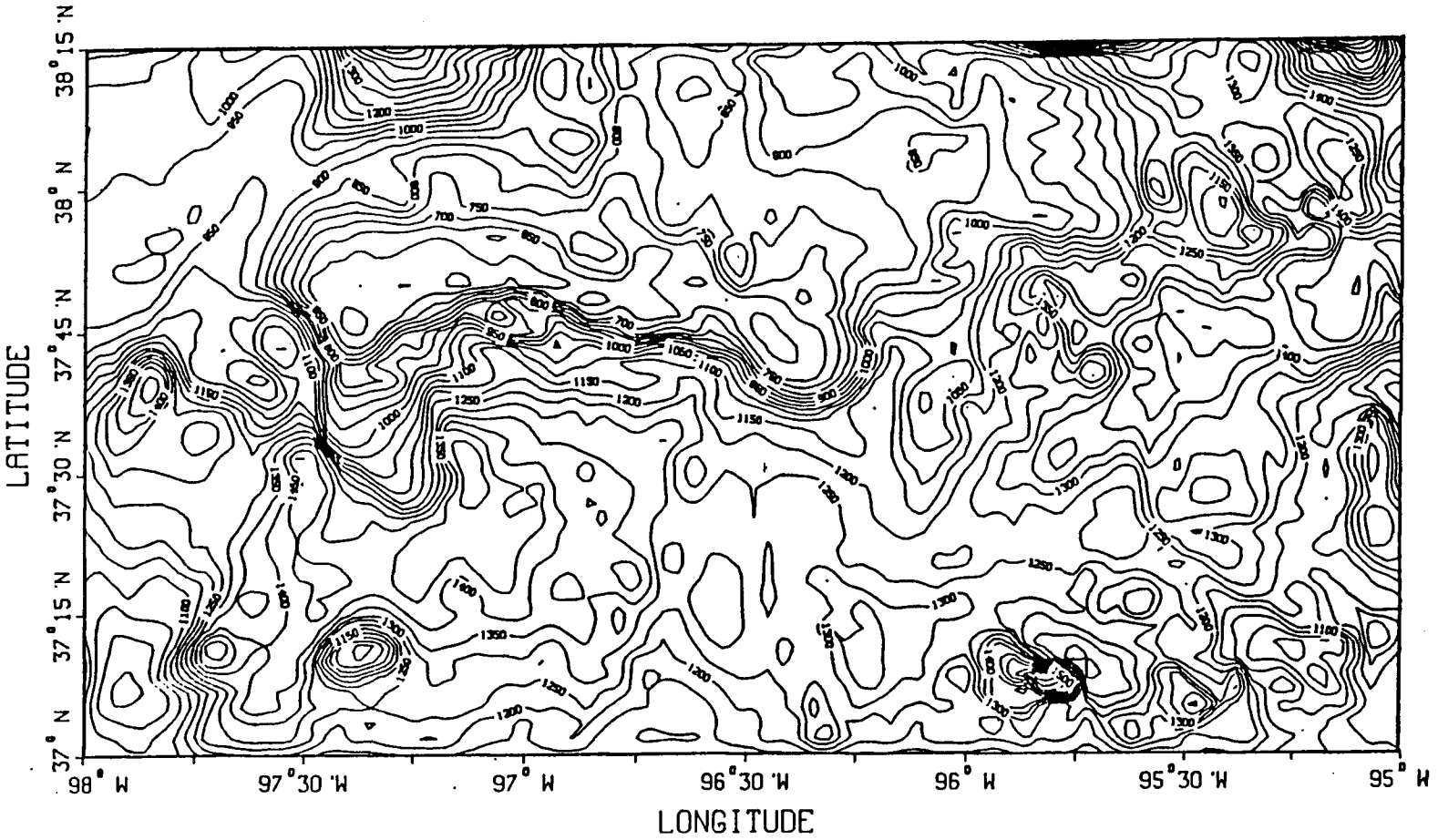

Figure 18. Reduced-to-the-pole magnetic anomaly map of southeastern Kansas. Contour interval is 50 gammas. Same scale as Figure 16.

the composite total intensity magnetic map (Figure 16) reveals some interesting differences. Positive anomalies, for example the strong positive anomalies in the southeast corner of the unreduced map, are shifted slightly to the north. The high wavenumber east-west trending lows within the center of the Wichita Magnetic Low are significantly broadened by reducing the data to the pole. The most prominent feature enhanced by this method is a steepened, east-west gradient which trends between 37° 45' N and 38° N. This gradient approximately delineates Yarger's (1981) proposed suture zone. The gradients on the north of the Wichita Low are greatly reduced.

Comparison of the reduced-to-the-pole map (Figure 18) with the Bouguer gravity anomaly map (Figure 17) shows a correlation between positive gravity anomalies and positive magnetic anomalies in the southeastern corner of the map. The oval-shaped magnetic low at 37° 45'N, 96° 30'N is correlated with a prominent Y-shaped gravity low which was interpreted by Woollard (1959) to be due to a granitic body. The broad, northeasterly-striking gravity high (+14 mgals) in the southwest corner of the map correlates with a broad magnetic high (+200 gammas). The long wavelength character of this magnetic anomaly suggests that it is a deep-seated feature. The magnetic and gravity data also suggest that this feature is terminated at approximately the proposed suture boundary. Significant uncorrelatable

gravity and magnetic anomalies are the two circular positive gravity anomalies within the Wichita Magnetic Low at 37o 45'N, 96o 45'W and 37o 45'N, 96o 15'W and the prominent circular negative magnetic anomaly at 37o 15'N, 97o 35'W that is located over a broad, gravity high.

Upward continuation of the data sets recalculates the potential field data at higher elevations, effectively attenuates higher wavenumber signals due to near-surface sources, and enhances larger wavelength signals. The reduced-to-the-pole, upward continued magnetic maps are shown in Figures 19 and 20. The 5 km upward continued map (Figure 19) highlights the steep gradient along the southern margin of the Wichita Magnetic Low and the broad, high to the south of the Wichita Low. The steep gradient along the southern side of the Wichita Magnetic Low and the high to the south are still evident in the 10 km upward continued map (Figure 20). Analysis of the upward continued maps suggests that the anomalies reflected by the Wichita Magnetic Low are not only high wavenumber lows, as seen in the reduced-to-the-pole map (Figure 18), but also long wavelength negative anomalies which are seen in the upward continued maps. If the high and low frequency anomalies correlate with shallow and deep sources respectfully, this implies that the Wichita Magnetic Low is a reflection of two sets of sources.

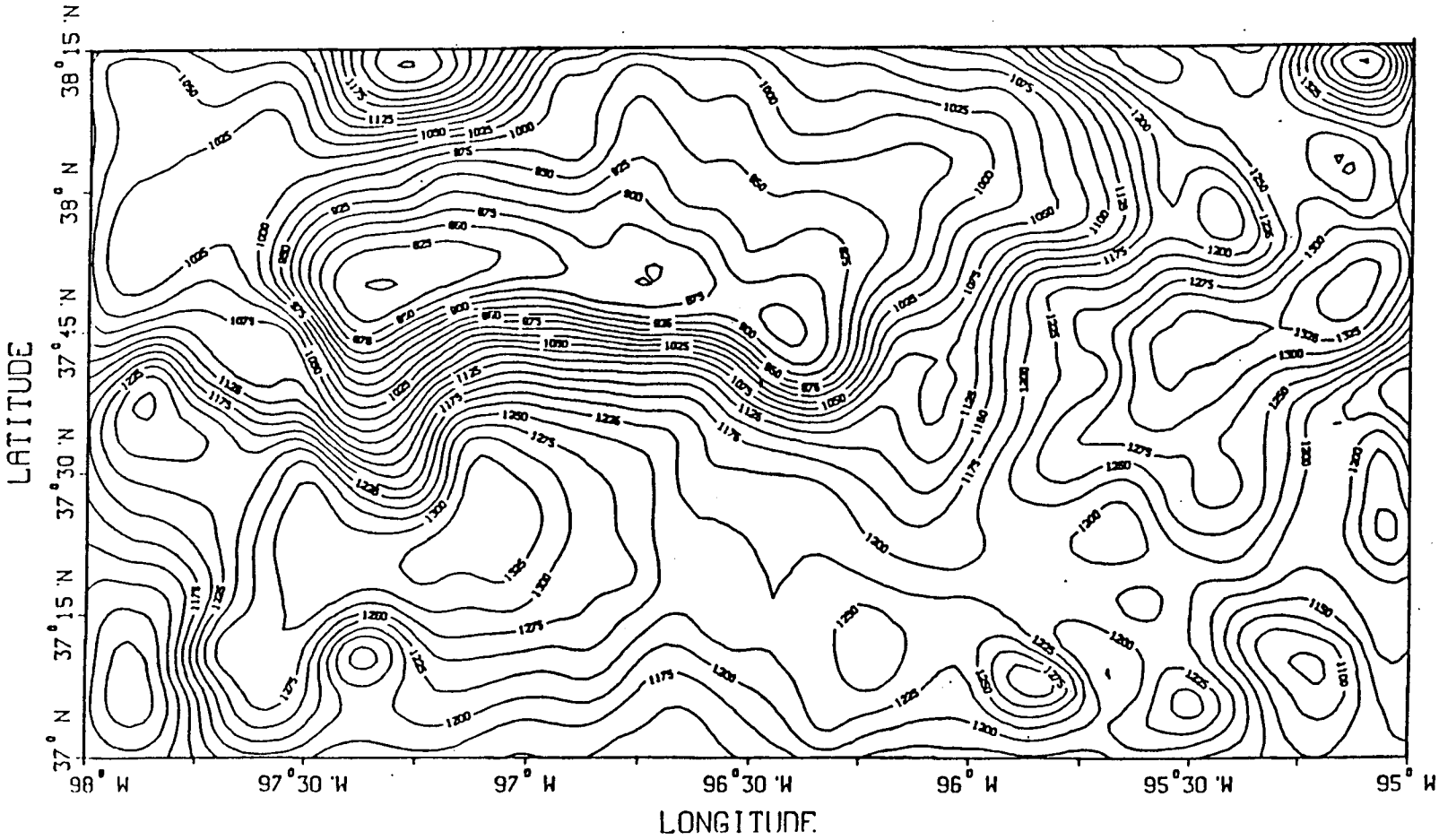

Figure 19. Reduced-to-the-pole and upward continued 5 km magnetic anomaly map of southeastern Kansas. Contour interval is 25 gammas. Same scale as Figure 16.

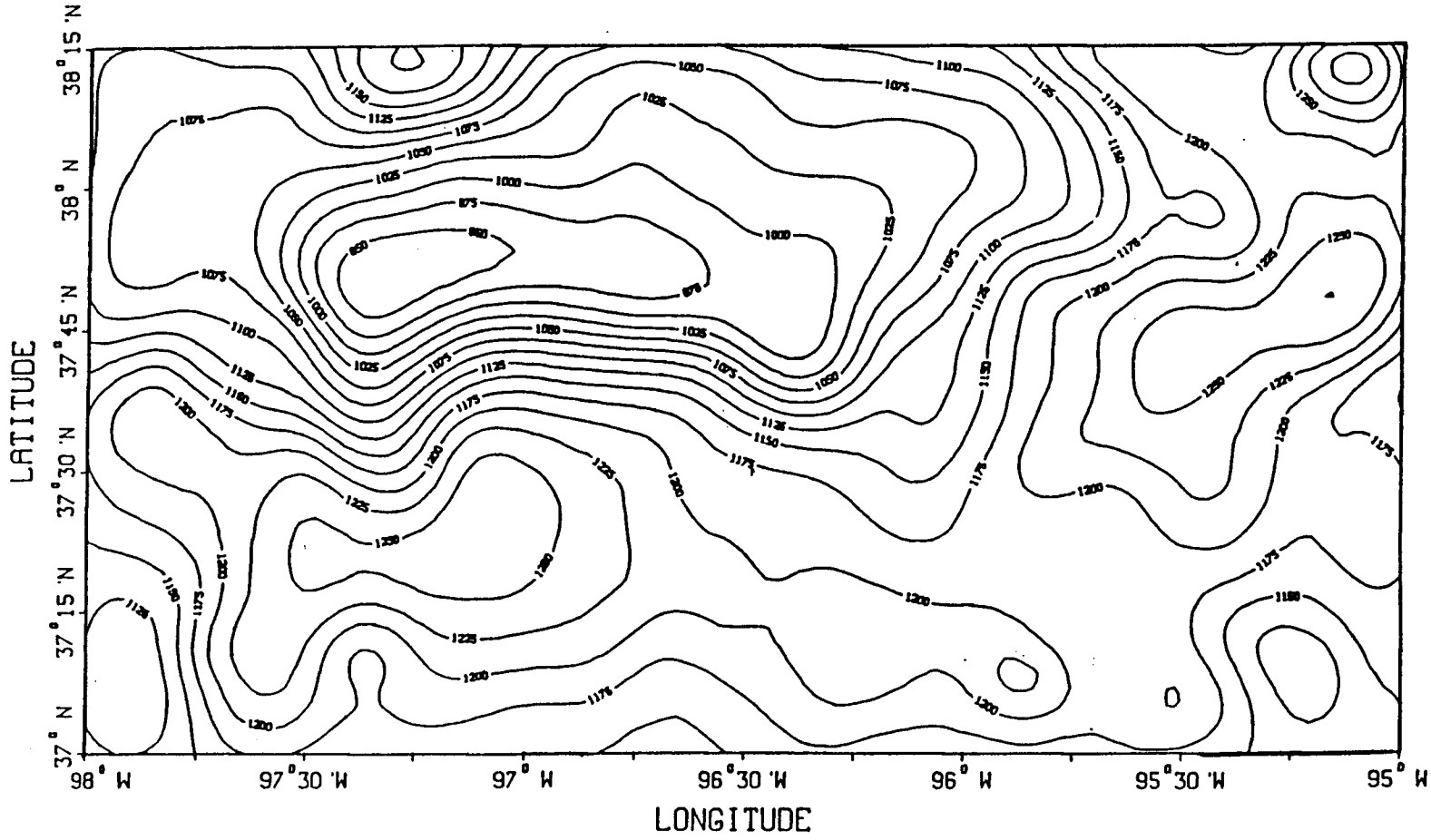

Figure 20. Reduced-to-the-pole and upward continued 10 km magnetic anomaly map of southeastern Kansas. Contour interval is 25 gammas. Same scale as Figure 16.

The gravity data were upward continued to 0.76 km above sea level (flight level of the aeromagnetic data), 5 km above sea level, and 10 km above sea level. The map continued to the flight level of the aeromagnetic data (Figure 21) has very few short wavelength sources attenuated. Note that the Bouguer gravity anomaly map (Figure 19) and the gravity map upward continued to flight elevation (Figure 21) are contoured at different intervals. The most significant change in the gravity map continued to the flight level is the change in the character of the Y-shaped gravity low and bordering gravity highs. The gradient north and east of the gravity high at 37° 50'N, 93° 50' W begins to reflect the shallow density contrast between the source of this anomaly and the Y-shaped low to the east and north. Analysis of the upward continued gravity maps (Figures 21, 22, and 23) shows a progressive attenuation of the high frequency anomalies (near-surface sources) and an increasingly noticeable east-west termination and attenuation of anomalies between 37° 45'N and 38° W which is best illustrated in the 10 km upward continued map (Figure 23).

An interpretation of the relative depths of given contrasting density sources is warranted from this upward continuation analysis. The two circular positive gravity anomalies located within the Wichita Magnetic Low (Figure 17) are systematically attenuated in the upward continued

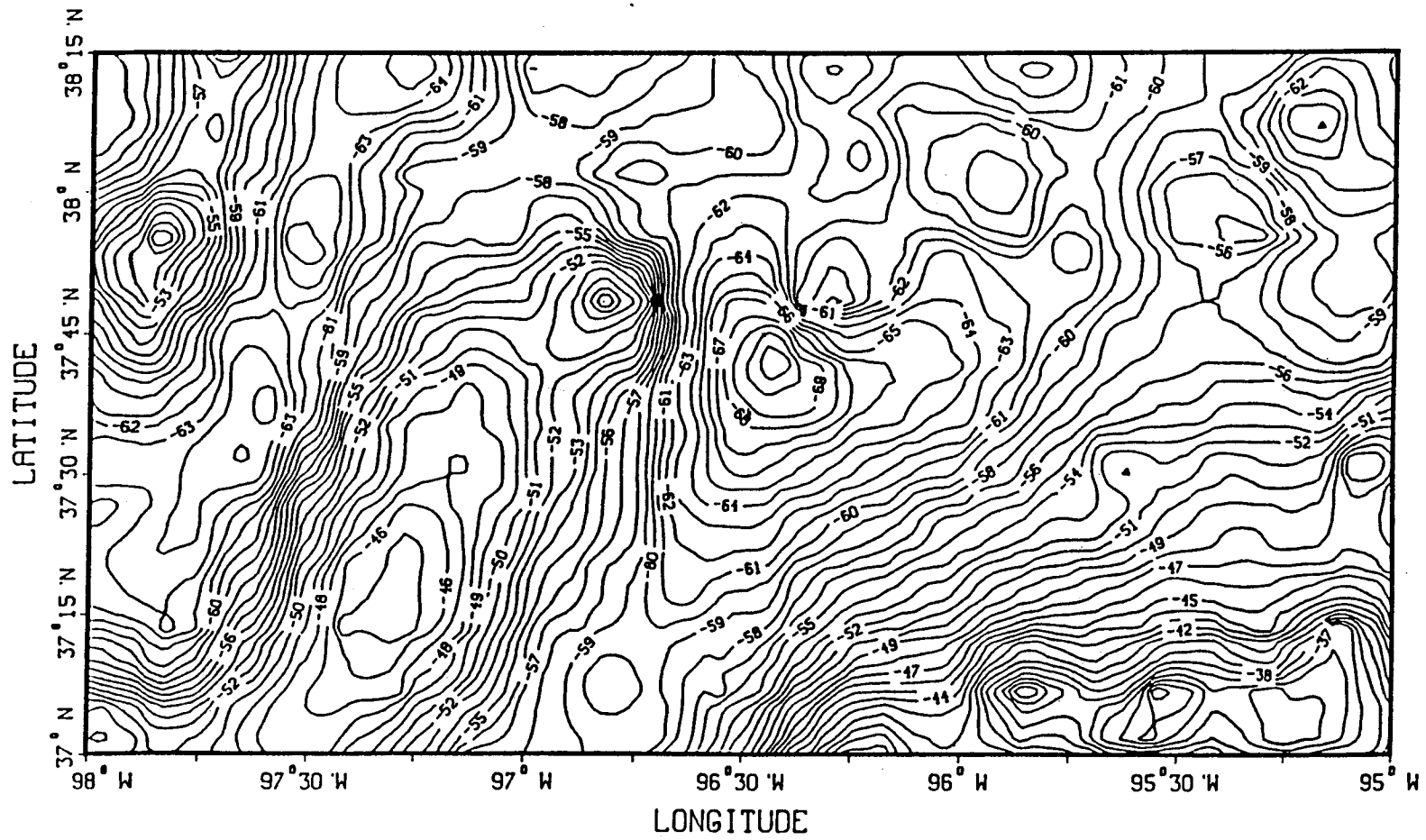

Figure 21. Upward continued to 0.76 km (flight elevation of the aeromagnetic survey) Bouguer gravity anomaly map of southeastern Kansas. Contour interval is 1 mGal. Same scale as Figure 16.

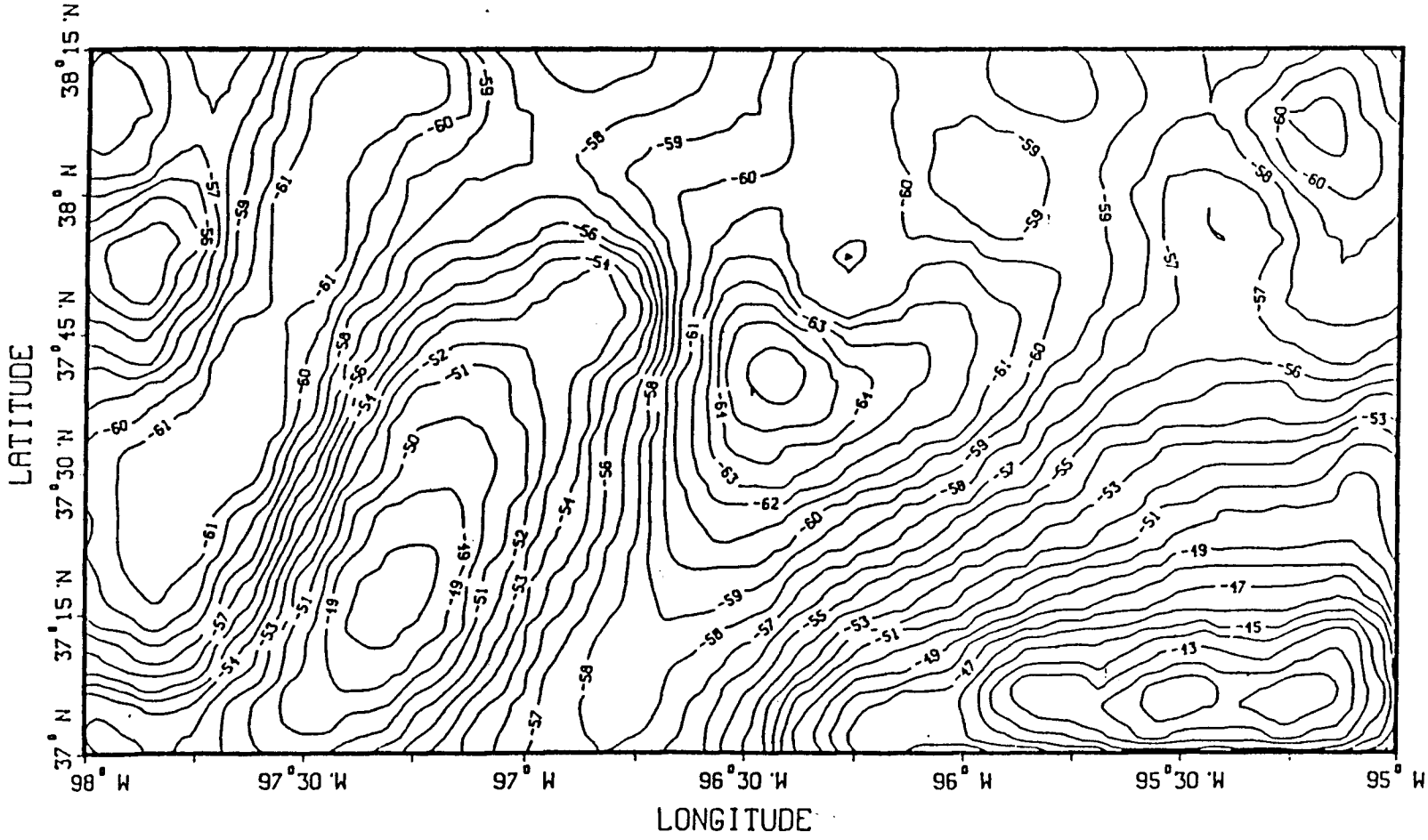

Figure 22. Upward continued to 5 km, Bouguer gravity anomaly map of southeastern Kansas. Contour interval is 1 mGal. Same scale as Figure 16.

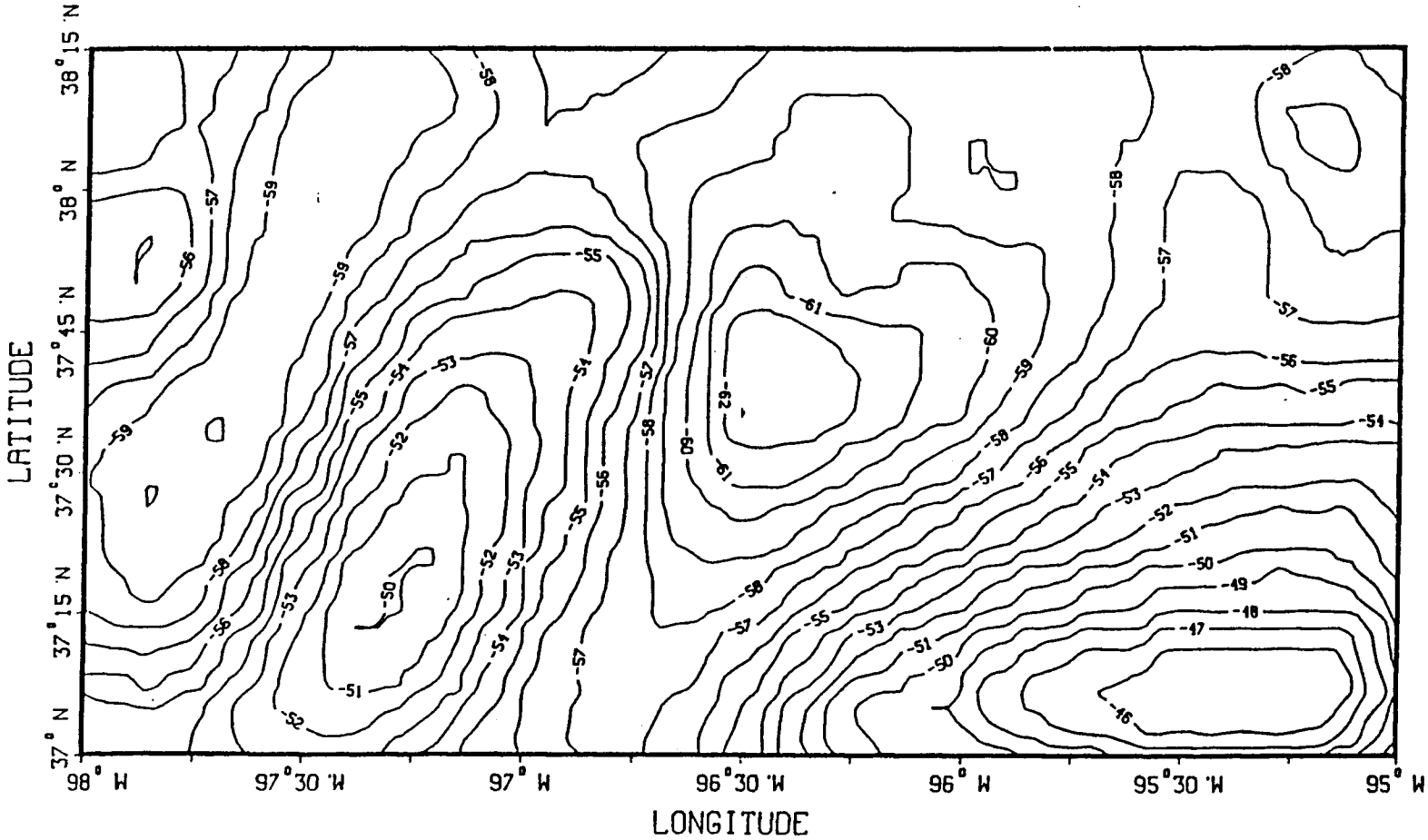

Figure 23. Upward continued to 10 km, Bouguer gravity anomaly map of southeastern Kansas. Contour interval is 1 mGal. Same scale as Figure 16.

maps. This suggests that these features are relatively shallow bodies. A similar analysis reveals that the northeast-striking positive and negative anomalies on the western half of Figure 17, the Y-shaped gravity low in the central part of Figure 17 and the broad positive anomaly in the southeast portion of Figure 17 are relatively deeply extending features.

In order to isolate the geometries of various gravity and magnetic anomalies, vertical derivative filters were applied. Because vertical derivatives enhance high wavenumbers, the 2 km upward continued, reduced-to-pole, magnetic data were used to reduce the effect of noise. The second vertical derivative map of the magnetic data is shown in Figure 24. The zero contour level of the second vertical derivative map roughly correlates to vertical source bodies. Within the Wichita Magnetic Low several of the proposed plutons of Gay (1984) (see Figure 2) are outlined by the zero contour level. Figure 25 is a plot of the first vertical derivative of gravity. The first vertical derivative gives an approximation of the anomaly source as the zero contour outlines the points of inflection from the original map. Interesting aspects of this map are the north-northeast trends in the northwesternmost part of the map and delineation of several anomalies such as the circular positive gravity highs within the Wichita Magnetic Low previously discussed.

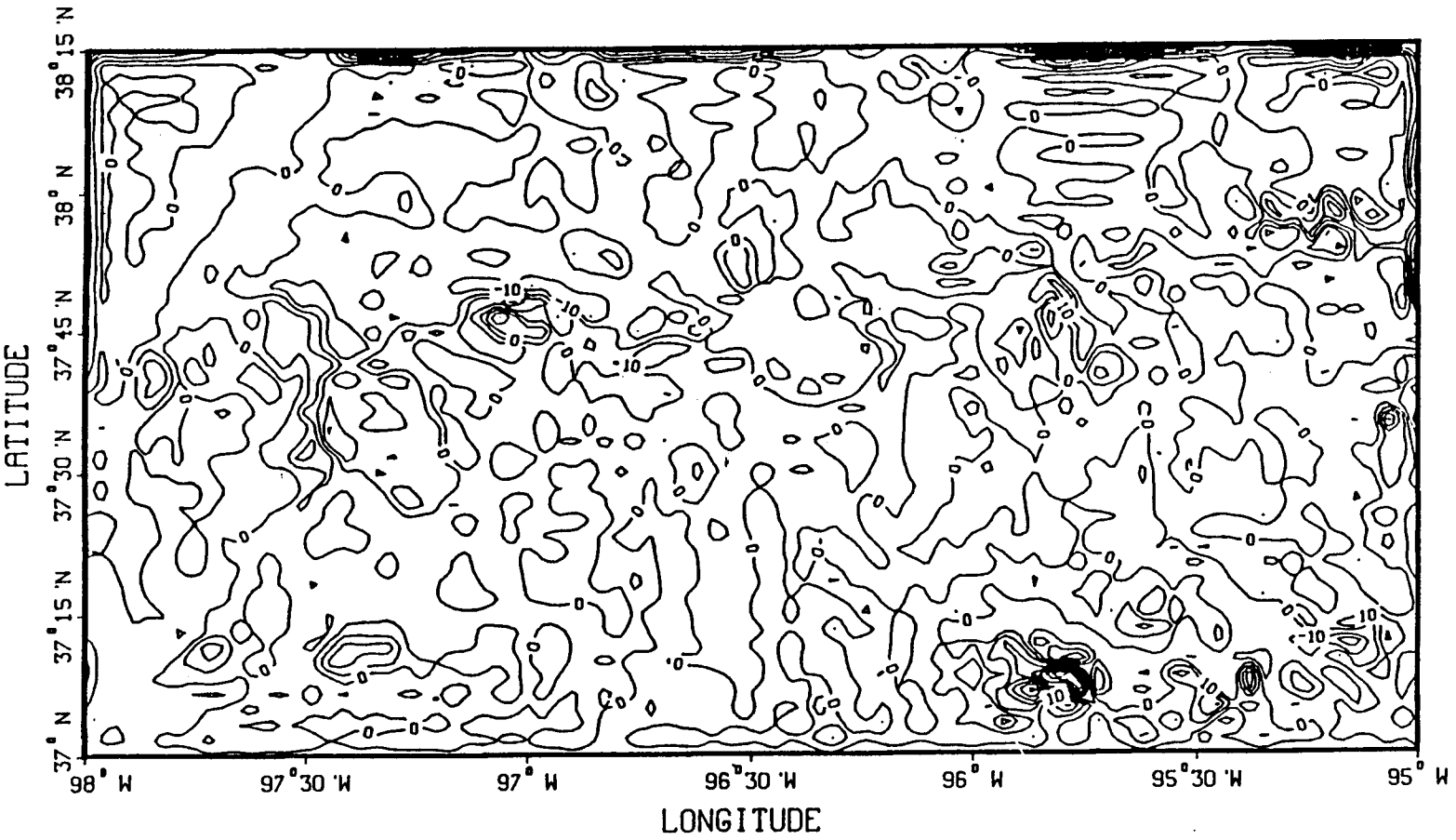

Figure 24. Second vertical derivative on 2 km upward continued, reduced-to-pole, magnetic anomaly map of southeastern Kansas. Contour interval is 10 gammas/km/km. Same scale as Figure 16.

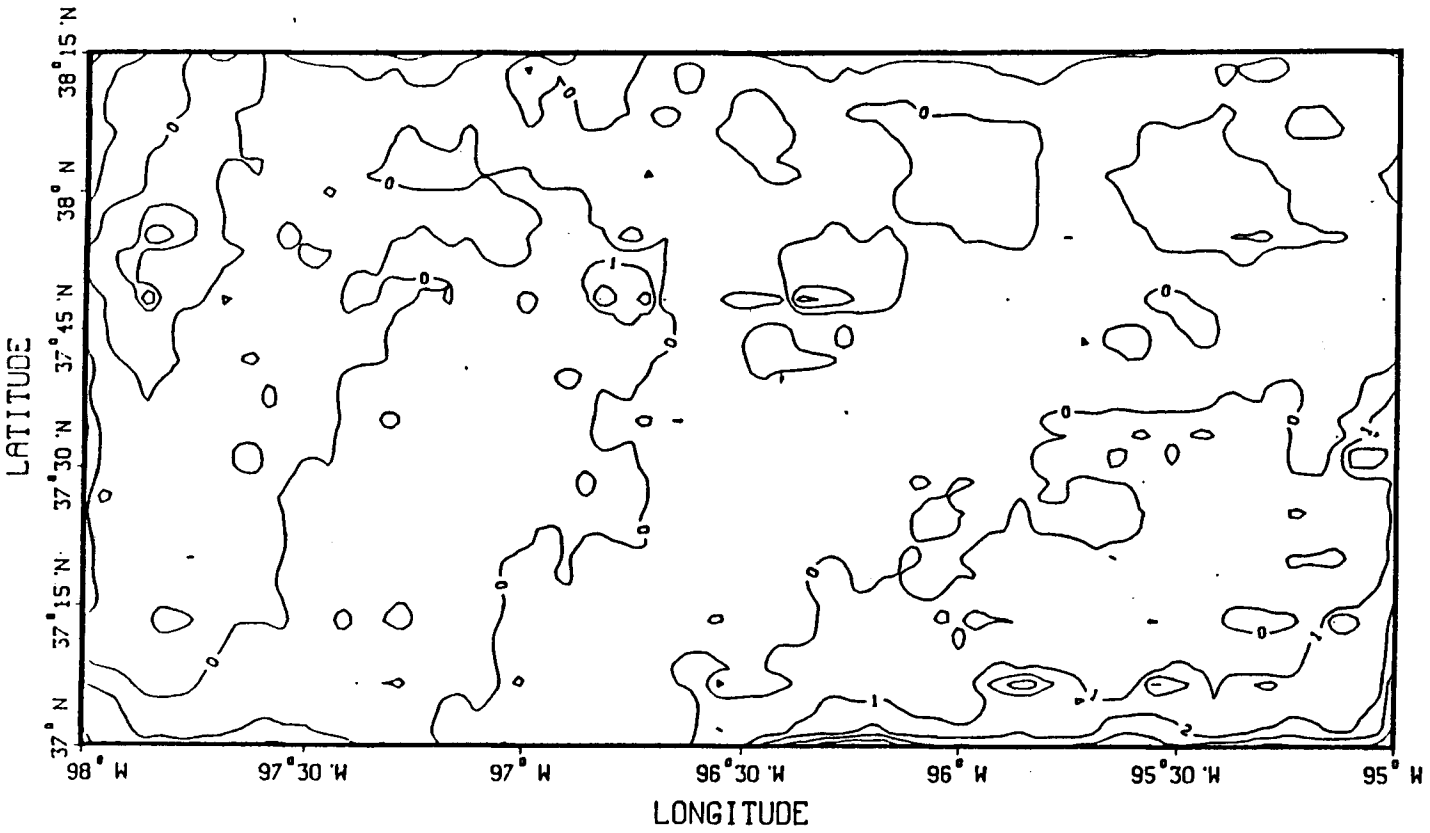

Figure 25. First vertical derivative of Bouguer anomaly map of southeastern Kansas. Contour interval is 1 mgals/km. Same scale as Figure 16.

V. MAGNETIC AND GRAVITY MODELING

The Wichita Magnetic Low is not associated with a correspondingly profound gravity anomaly. This is illustrated in Figure 26 by several magnetic and gravity profiles along coinciding traverses plotted across southeastern Kansas. It should be noted that the magnetic profiles have not been reduced-to-pole, and therefore there will be minor problems in directly correlating magnetic and gravity anomalies. However, these north-south profiles illustrate that the prominent magnetic minimum does not have a correspondingly distinct gravity anomaly. This is unexpected because the source of the magnetic minimum, in particular felsic igneous rocks, commonly have a negative density contrast with the country rock and therefore generate a negative gravity anomaly. Further complicating the correlation of the gravity and magnetic anomalies is the gravity effect of the Midcontinent Rift System which has dramatically affected the gravity field in the western portion of the study area. Broad northeast-trending gravity anomalies occur across the western end of the Wichita Magnetic Low. A subtle correlation appears between the gravity and magnetic anomalies (Figure 23 and 20) that were upward continued to 10 km in that there is an east-

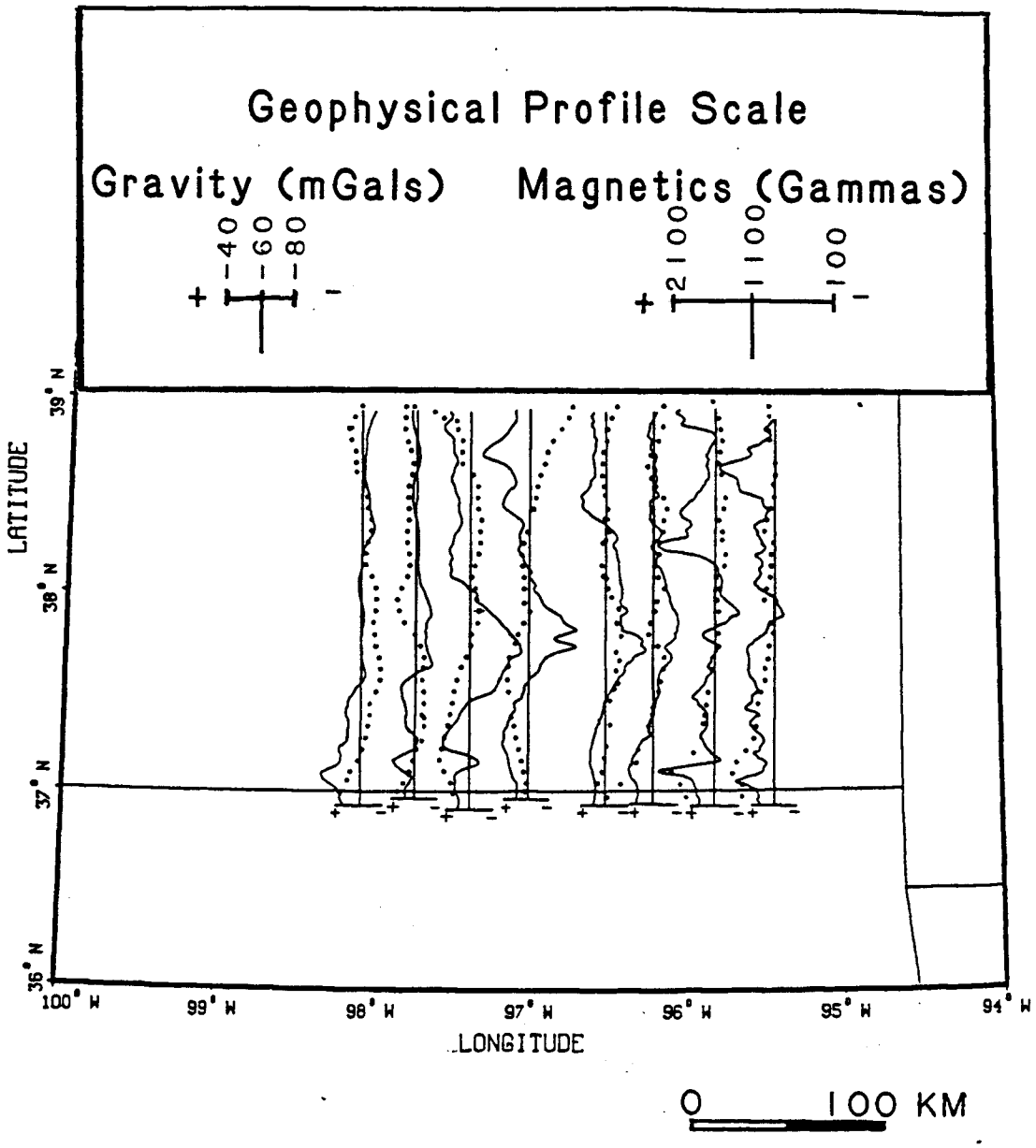

Figure 26. Magnetic and gravity profiles over the Wichita Magnetic Low in southeastern Kansas (dots = gravity, curves = magnetics) plotted on datum level coincident with profile location.

west trending gradient in the magnetic data and a noticeable truncation or attenuation of gravity anomalies between 37o 45'N and 38oN.

Modeling magnetic and gravity profiles across the Wichita Magnetic Low is complicated by the lack of obvious correlation between the magnetic minimum and the gravity data. Choosing a profile perpendicular to the Wichita Magnetic Low that could be modeled two-and-one-half dimensionally using magnetics and gravity proved to be difficult across the western portion of the magnetic minimum due to the dominant effect of the Midcontinent Rift System previously described. Two-and-one-half dimensional modeling takes into account the strike length of the source perpendicular to the profile to be modeled. The effects of a body slightly off the profile or not perpendicular to the profile make two-and-one-half dimensional modeling a poor approximation. For this reason, a gravity and magnetic profile was chosen in the eastern end of the Wichita Magnetic Low as shown in Figures 27 and 28. This profile intersects an oval-shaped magnetic low at 37o 45'N and a prominent Y-shaped gravity minimum previously mentioned.

Two-and-one-half dimensional modeling programs developed by Shuey and Pasquale (1973) and based on a two dimensional modeling program by Talwani et al. (1959) were used to model these profiles. Seismically determined depths to the Moho, drill hole lithologies and depths to

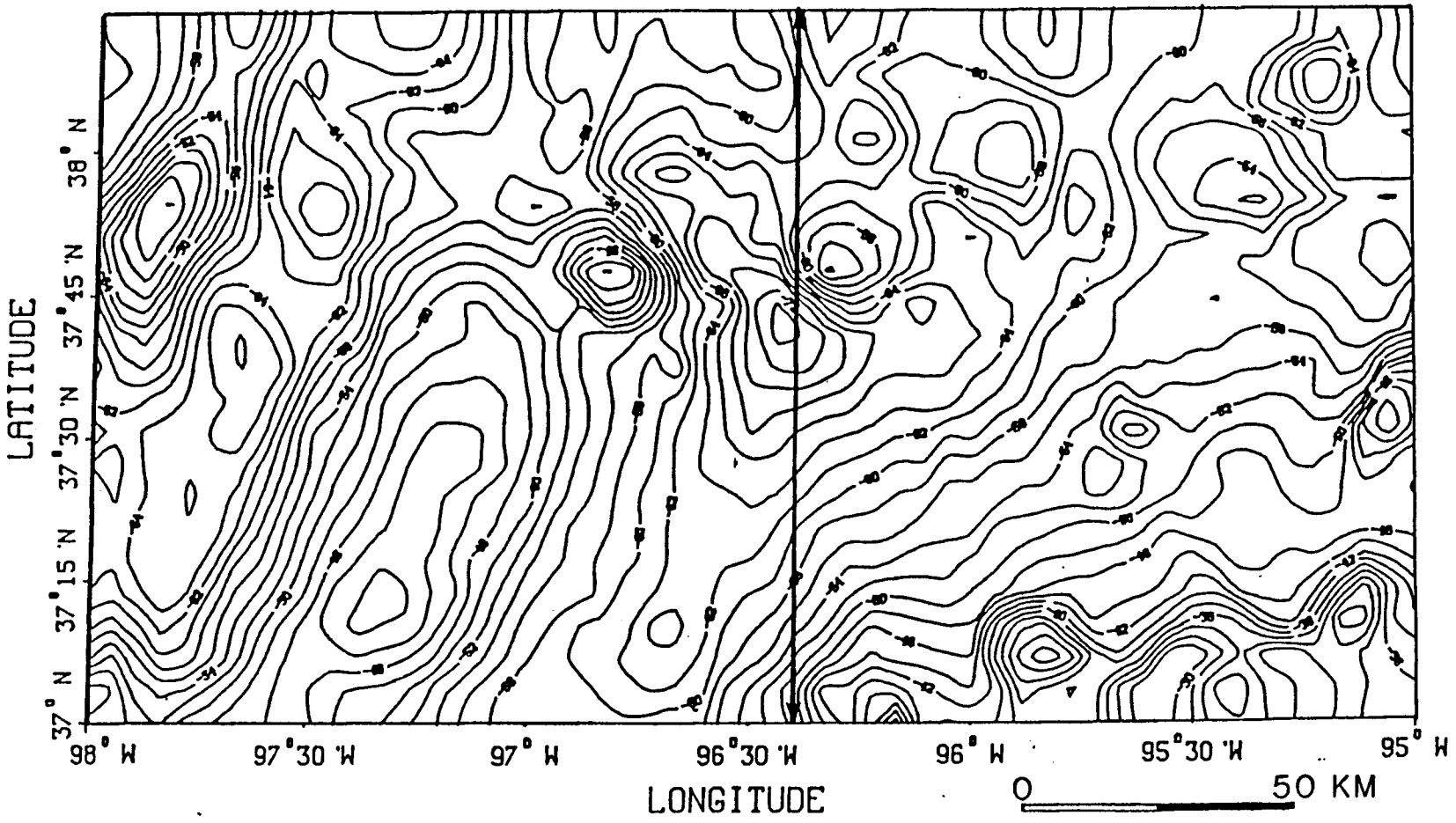

Figure 27. Bouguer gravity map showing location of profile used in two-and-one-half dimensional modeling. Contour interval is 2 mGals.

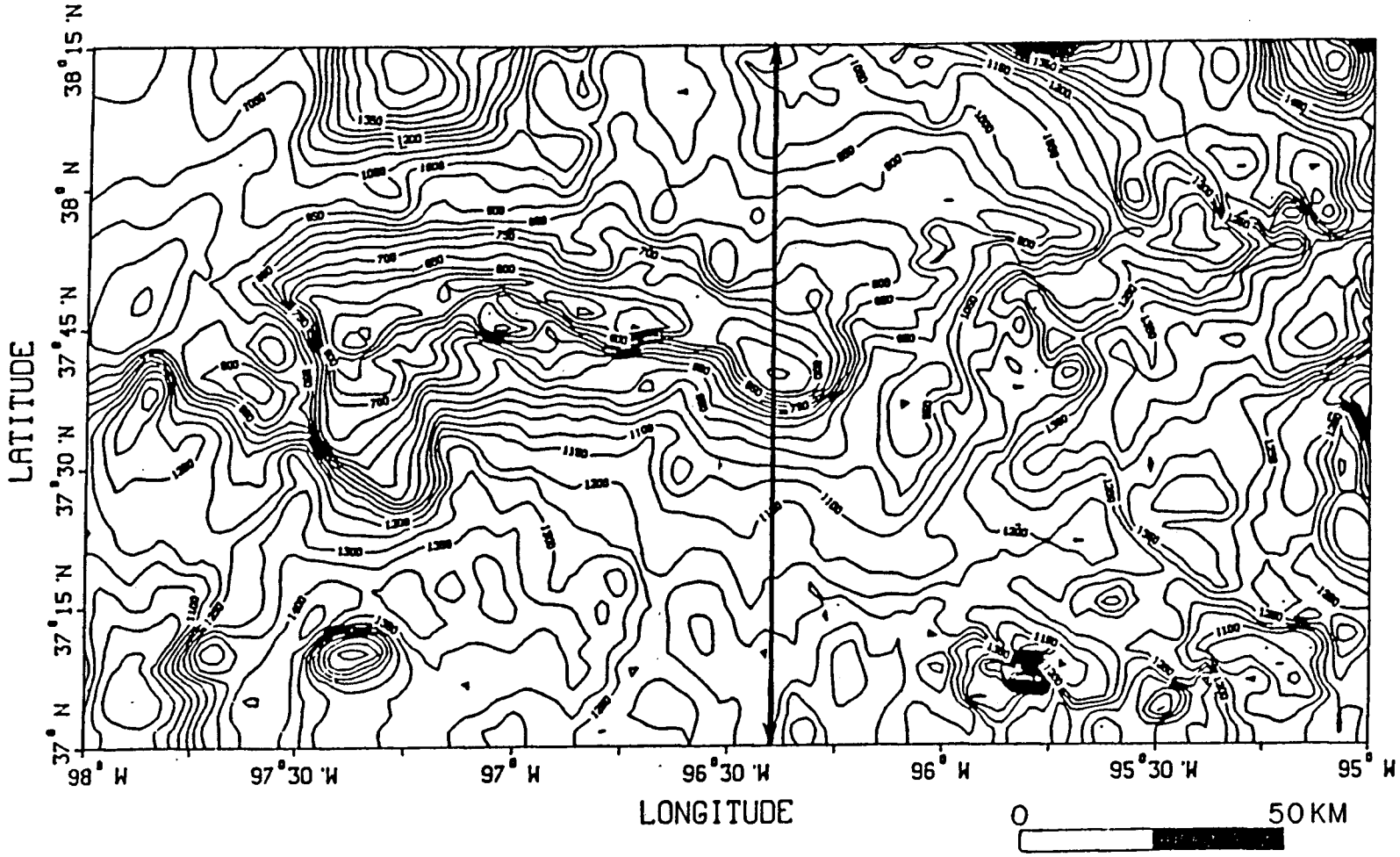

Figure 28. Total intensity magnetic anomaly map showing the location of the profile used in the two-and-one-half dimensional magnetic modeling. Contour interval is 50 gammas.

basement, and relative depth and geometries of anomalous sources derived from the processing analyses were used as constraints on the modeling. The strike length of each body was estimated by inspecting the gravity and magnetic maps as well as the vertical derivative maps. Since there is a fairly large sampling of depths to the Precambrian basement by drilling, a grid of these depths were used to constrain the top of the basement. A simplistic two-layered crust with a horizontal contact between the upper and lower crustal layers and a gentle southerly-dipping Moho was assumed. Although the depth to the boundary between the upper and lower crust is not well-defined, a depth of 15 km to this assumed horizontal contact was an approximation derived from the COCORP survey directly to the north of the study area (Serpa et al., 1984). The Moho depths of 42 km and 46 km were taken from Stewart (1968) and Mitchell and Landisman (1970) respectfully. The density used for the sedimentary rocks in this study was estimated to be 2.6 gm/cc (Lam, 1986). Since these rocks are relatively flat-lying, any gravity anomaly caused within the Paleozoic sedimentary sequence would have relatively long wavelengths. The upper and lower crustal layers were assigned densities of 2.70 gm/cc and 2.95 gm/cc respectfully. An upper mantle density of 3.30 gm/cc was assumed to be constant over the entire study area.

Allingham (1976) investigated susceptibilities of outcropping crystalline basement rocks to the east of the study area in the St. Francois Mountains of Missouri. His results were that Graniteville-type granites in the Belleview pluton had susceptibilities of nearly nil to 0.002 emu/cc, while other granites had susceptibilities as high as 0.003-0.004 emu/cc.

In this investigation the sedimentary cover over the Precambrian basement was assumed to be non-magnetic (Yarger, 1983). The crust was assumed to be magnetic to the Moho, while the upper mantle was assumed to be non-magnetic (Wasilewski et al., 1979).

Wichita Magnetic Low

The magnetic profile was upward continued to 10 km to attenuate the effects of shallow sources and to obtain the magnetic field due to regional crustal variations. The problem of ambiguity with respect to the direction of dip of the suture was investigated by modeling the 10 km upward continued data with northerly-dipping (45°), southerly-dipping (45°), and vertical suture models. Figures 29, 30, and 31 show the regional magnetic field calculated for these models. Susceptibility contrasts of 0.0015 and 0.0025 emu/cc were needed in the upper and lower crust respectfully to model these upward continued data. The

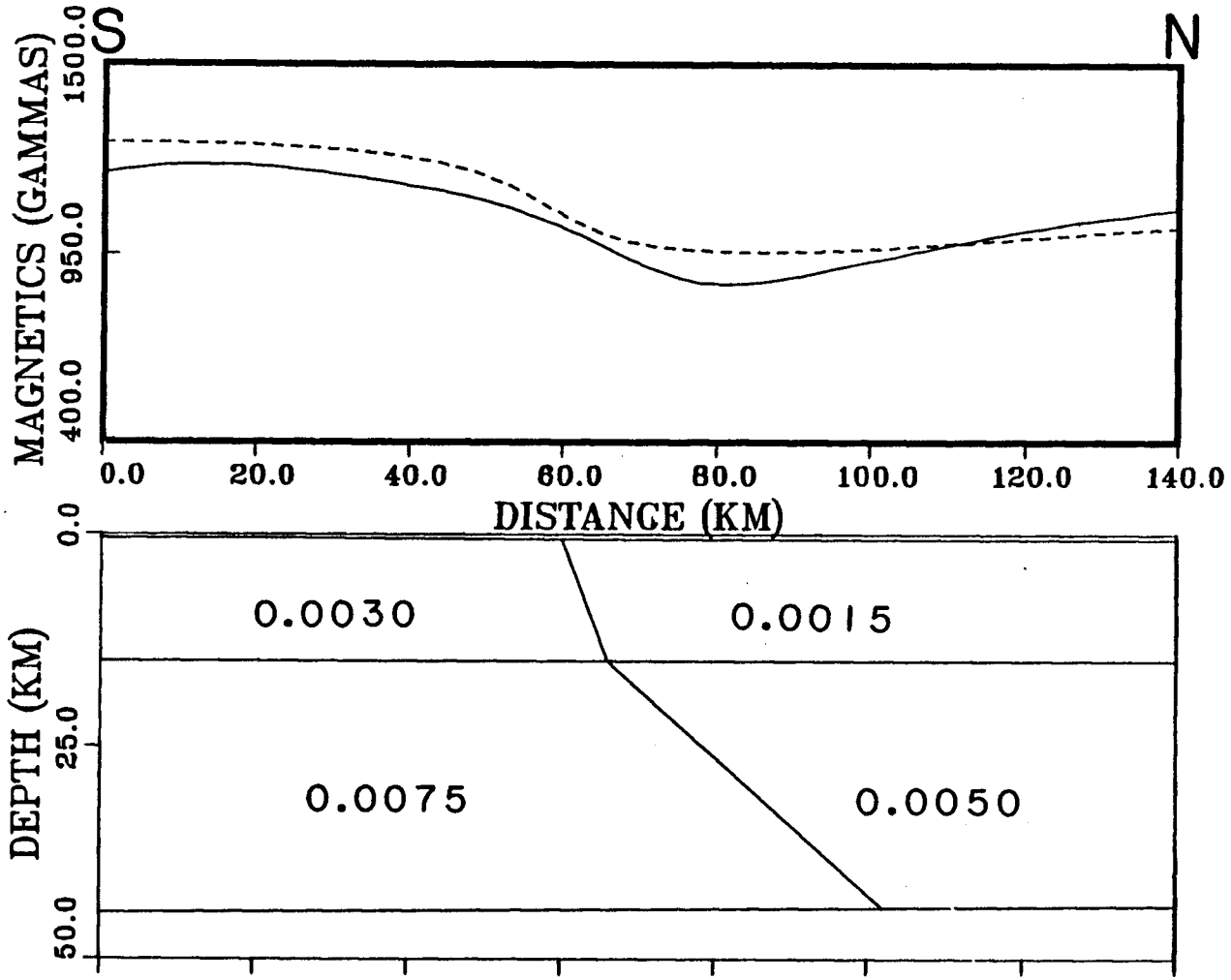

Figure 29. Two-and-one-half dimensional model of the 10 km upward continued magnetic anomaly data using a northerly-dipping crustal boundary model. Susceptibilites are emu/cc. Dashed line is calculated, solid line is observed.

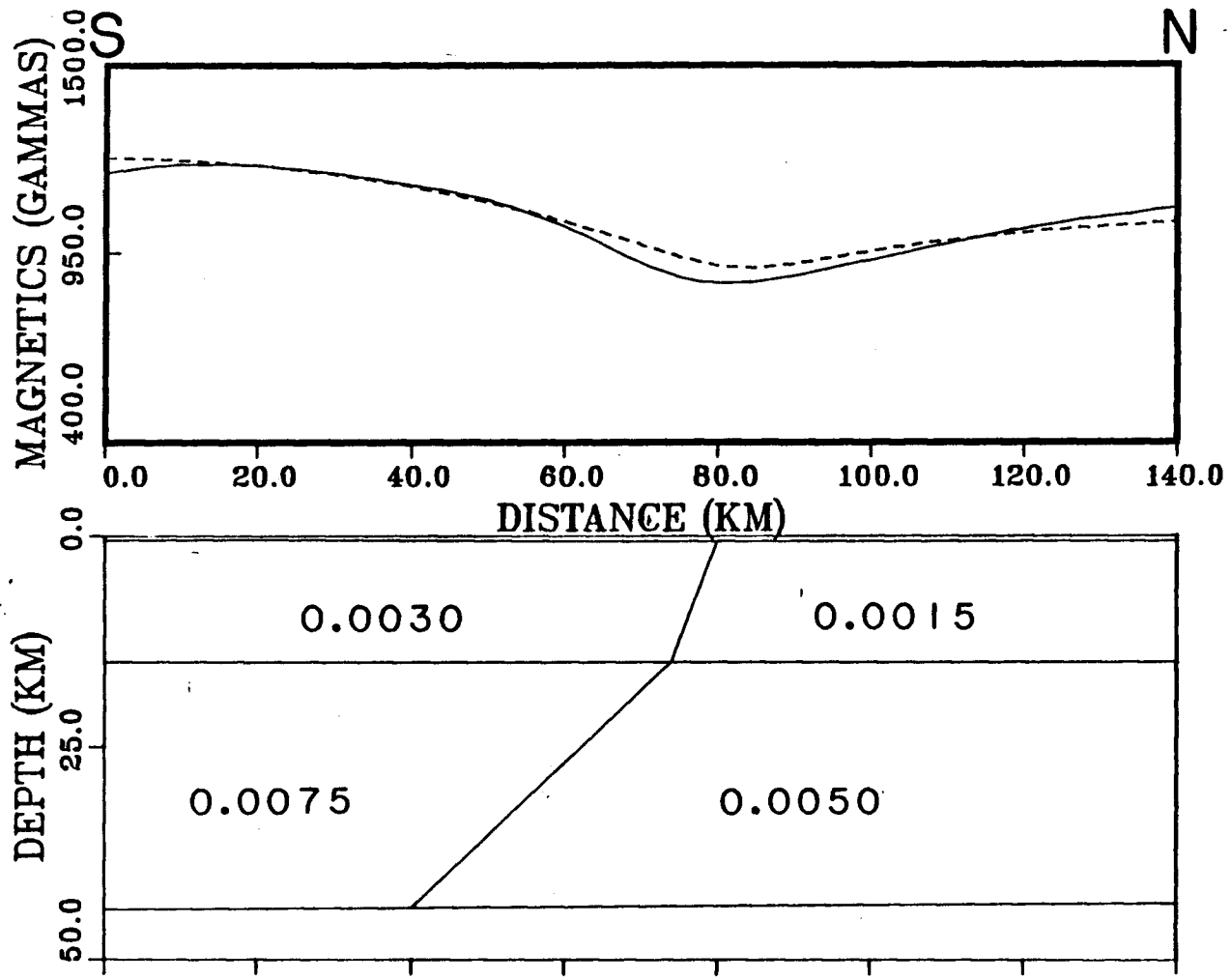

Figure 30. Two-and-one-half dimensional model of the 10 km upward continued magnetic anomaly data using a southerly-dipping crustal boundary model. Susceptibilities are emu/cc. Dashed line is calculated, solid line is observed.

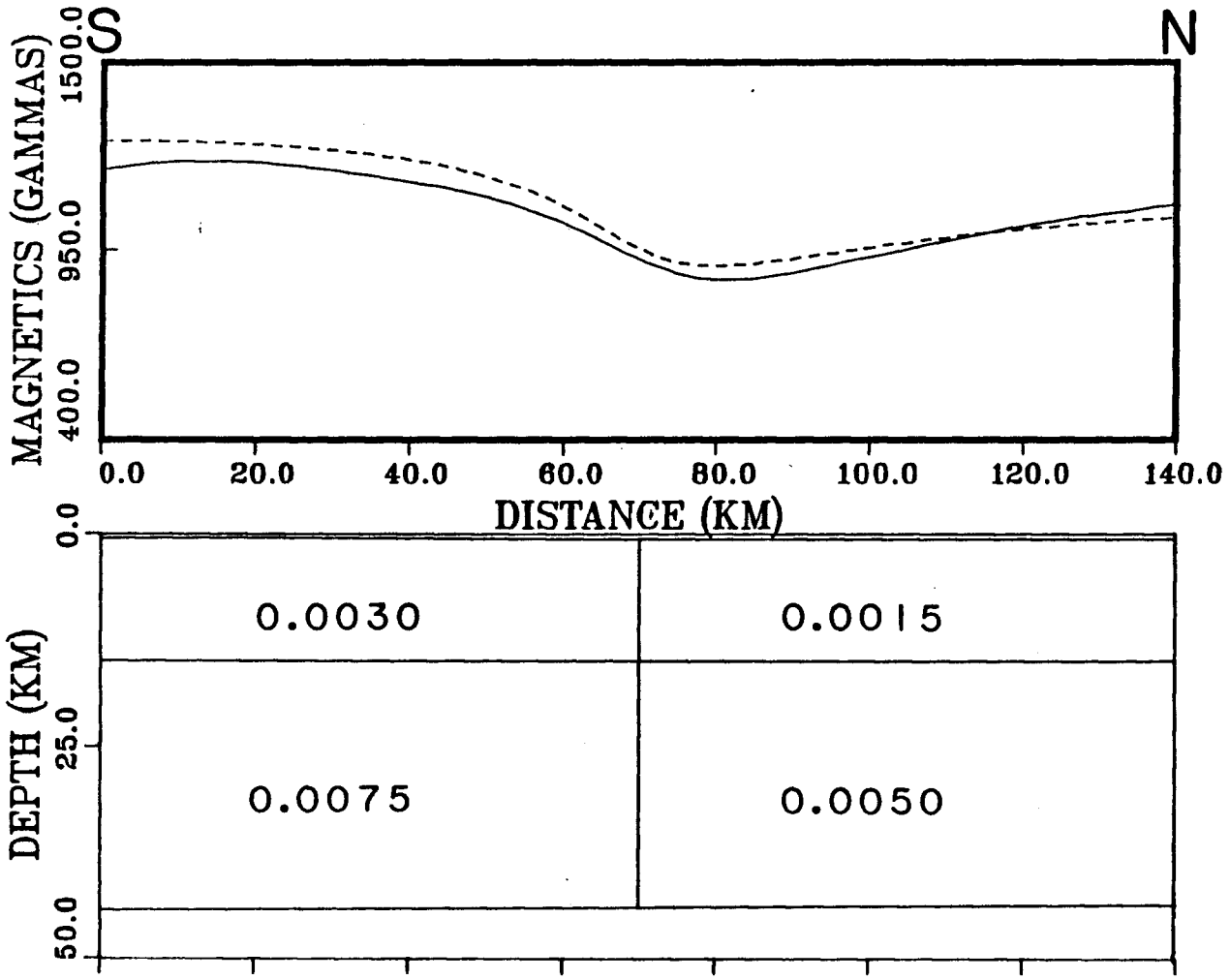

Figure 31. Two-and-one-half dimensional model of the 10 km upward continued magnetic anomaly data using a vertical crustal boundary model. Susceptibilities are emu/cc. Dashed line is calculated, solid line is observed.

southerly-dipping and vertical models, as shown in Figures 30 and 31 respectively, closely approximate the regional magnetic field, while the northerly-dipping model, Figure 29, does not approximate the 10 km upward continued data.

Shallow sources were added to the initial 10 km upward continued southerly-dipping and vertical suture models to approximate the observed magnetic and gravity data. Magnetic and gravity models with coinciding bodies were achieved, however, some of the gravity and magnetic anomalies do not have corresponding density and susceptibility contrasts as shown in Figures 32, 33, 34, and 35.

In the magnetic models (Figures 32 and 34) there are large susceptibility contrasts between the major juxtaposed crustal blocks. It was found that the upper crust in the southern block had to have a much higher susceptibility if the contrast between it and the nearly non-magnetic, granitic plutons were to fit the high wavenumber negative anomaly. On the other hand, the gravity models (Figures 33 and 35) have relatively minor density contrasts in the lower crust, while density contrasts in the upper crust are related to local sources. The subtle gravity anomalies are reflected by the small density contrasts in the upper crustal bodies and between the lower crustal blocks.

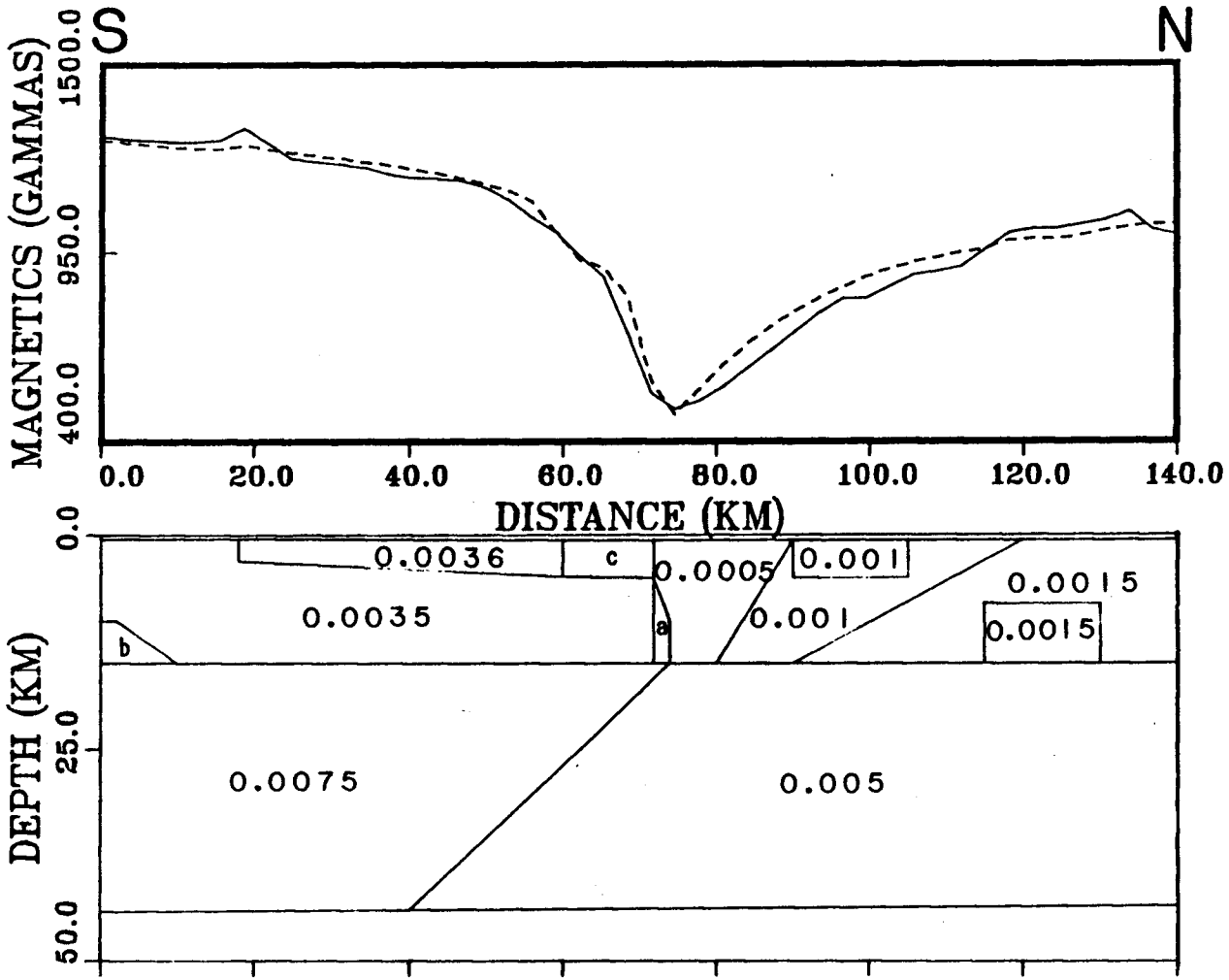

Figure 32. Two-and-one-half dimensional model of the observed magnetic anomaly data using a southerly-dipping crustal boundary model. The susceptibilities denoted by letters are: a = 0.0015 emu/cc, b = 0.0045 emu/cc, and c = 0.0028 emu/cc.

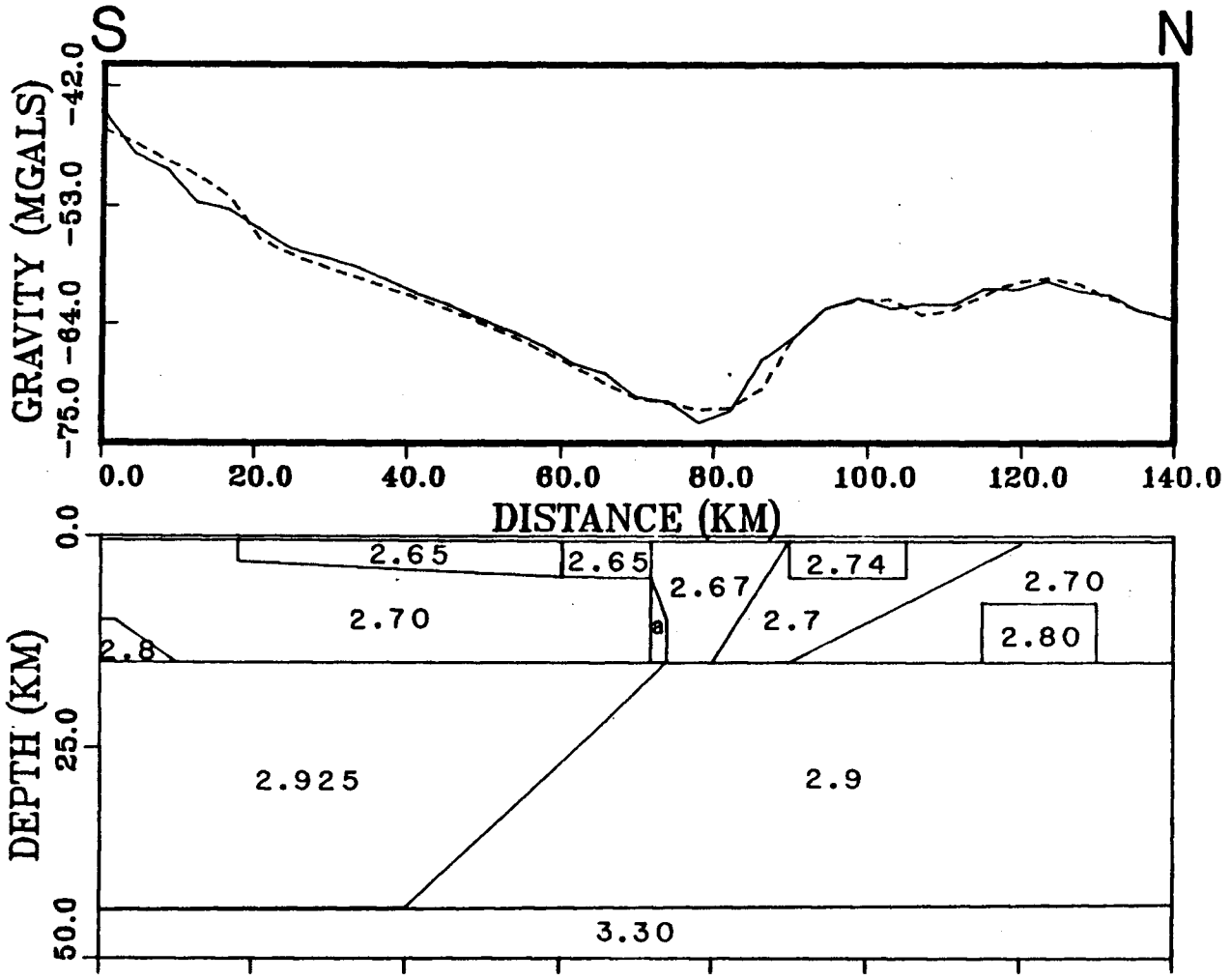

Figure 33. Two-and-one-half dimensional model of the observed gravity anomaly data using the southerly-dipping crustal boundary model. The density denoted by a = 2.68 gm/cc. Dashed line is calculated, solid line is observed.

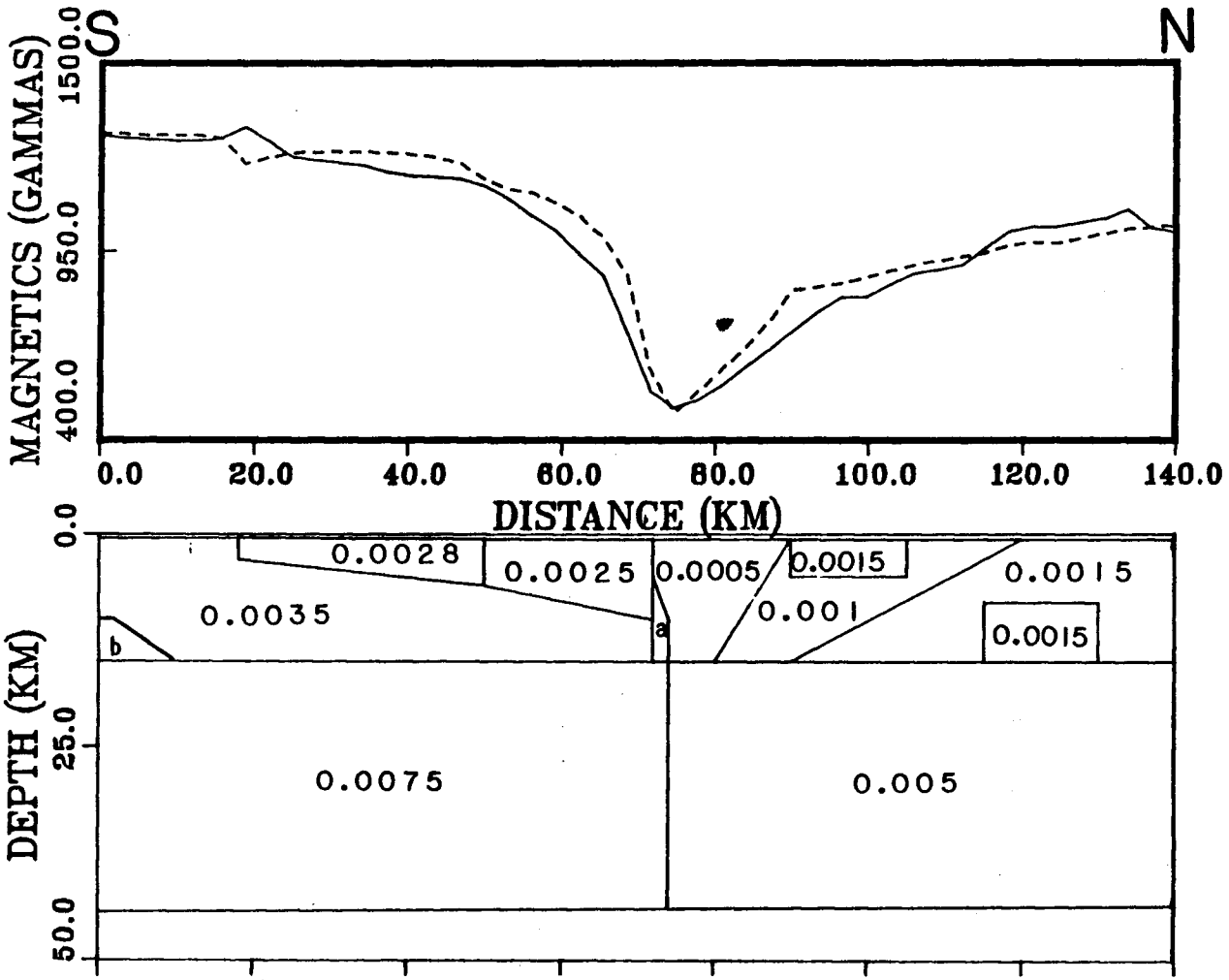

Figure 34. Two-and-one-half dimensional model of the observed magnetic anomaly data using the vertical crustal boundary model. The susceptibilities denoted by letters are: a = 0.0015 emu/cc and b = 0.0045 emu/cc. Dashed line is calculated, solid line is observed.

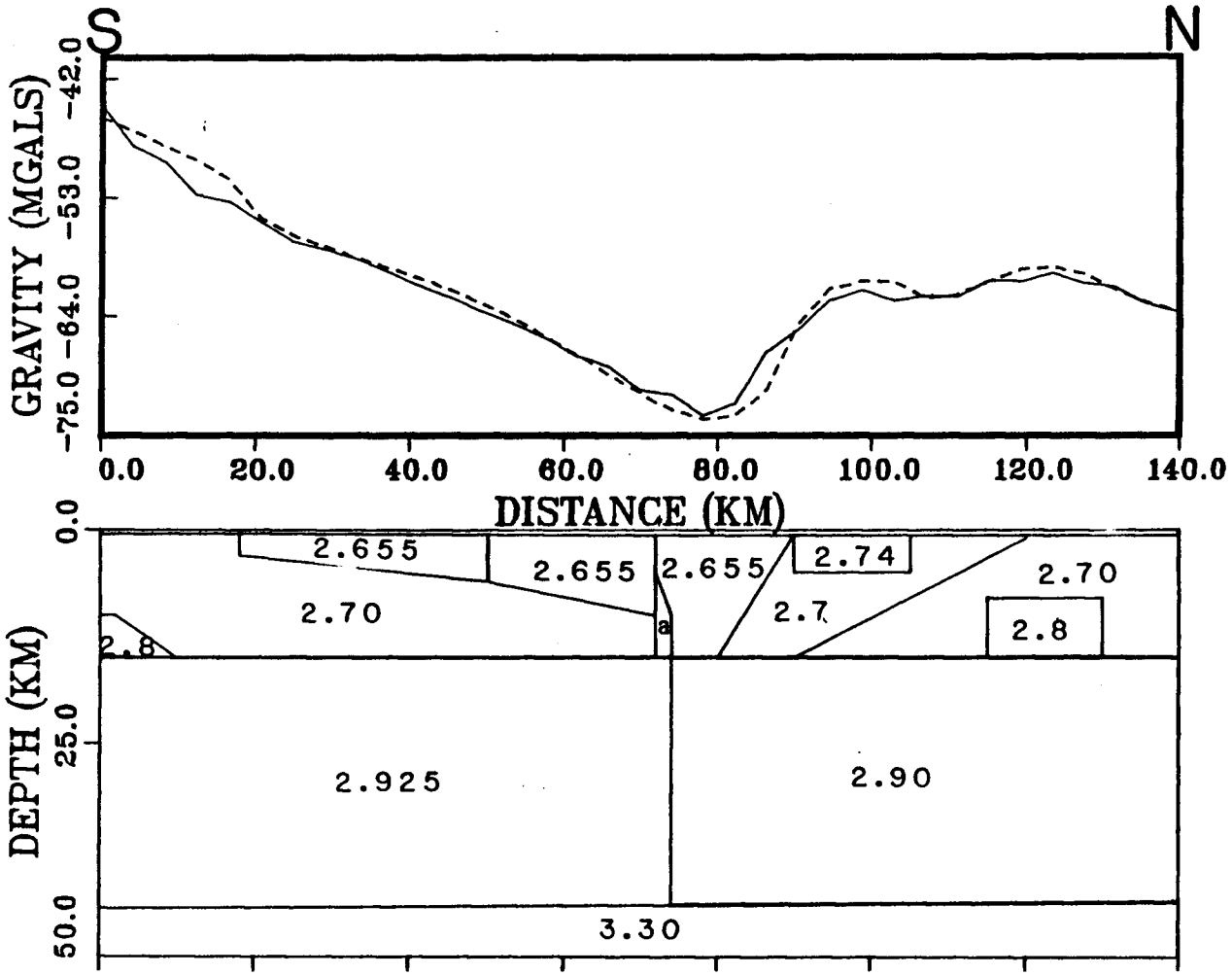

Figure 35. Two-and-one-half dimensional model of the observed gravity anomaly data using the vertical crustal boundary model. The density denoted by a = 2.68 gm/cc. Dashed line is calculated, solid line is observed.

Piedmont Anomaly

A three dimensional modeling program called XMANIK was used to model a circular magnetic low in the eastern Wichita Magnetic Low that Gay (1984) termed the Piedmont pluton (Figure 2). This modeling program uses horizontal laminae to approximate an anomalous source. In this study, the oval-shaped magnetic low at 37° 45'N, 96° 25'W in Figure 16 will be termed the Piedmont anomaly. The very steep gradients of the Piedmont anomaly suggest that the source extends close to the basement-sedimentary rock interface.

The isolated residual map (Figure 36), that was determined by the intersecting-profile method, was used in the three-dimensional modeling. The isolated Piedmont anomaly is the oval-shaped low in Figure 36 (left-hand side). Note that this residual map does not completely isolate the the anomalous Piedmont anomaly from the regional east-west linear low related to the suture.

Results of the two-and-one-half dimensional model were used for an initial three dimensional approximation of the Piedmont pluton. Adjustments to this three dimensional model resulted in a calculated magnetic field as shown in Figure 36. Figure 37 is a comparison of the observed

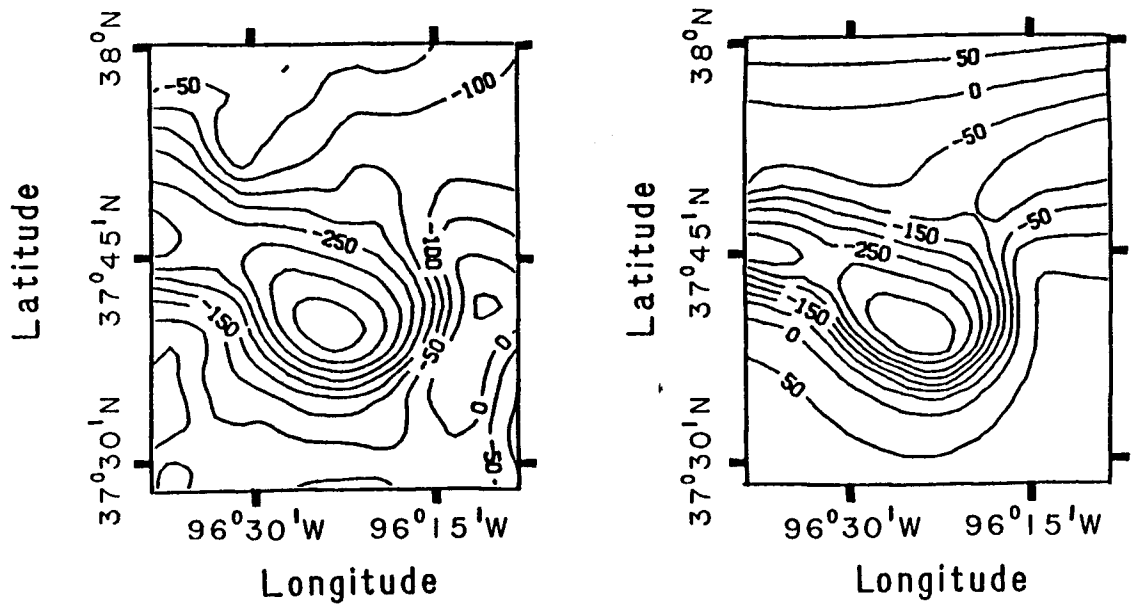

Figure 36. Plot on the left is the isolated residual magnetic map over the Piedmont anomaly. Plot on the right is the magnetic field calculated by three dimensional modeling over the Piedmont pluton. Contour interval is 50 gammas.

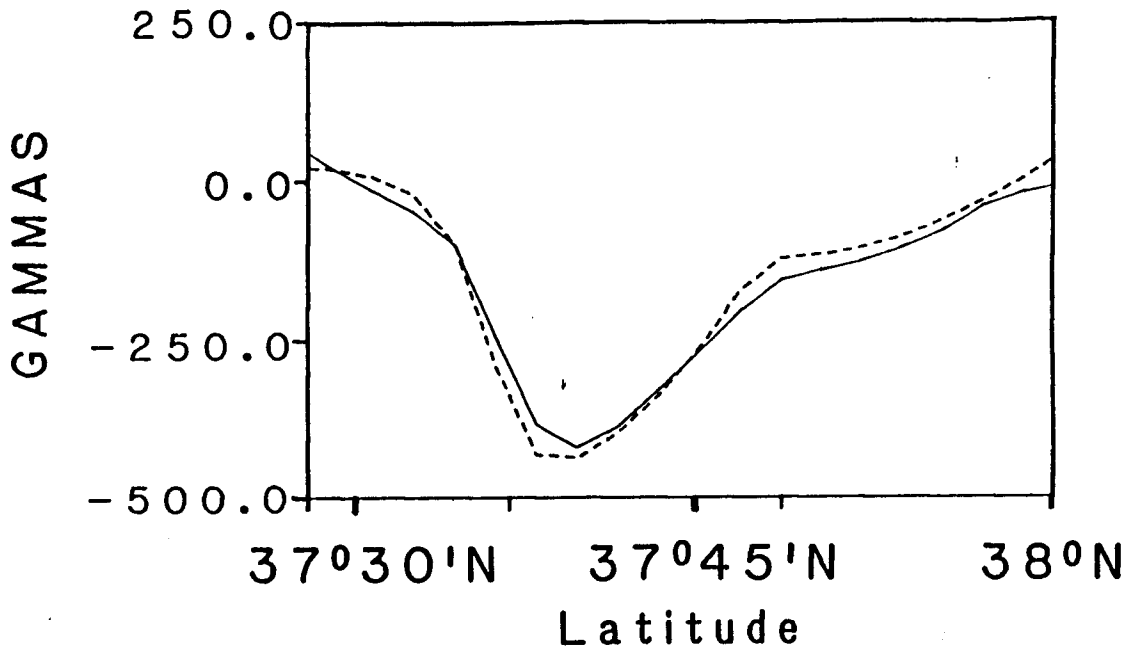

Figure 37. Comparison of the observed (solid) and the calculated (dashed) magnetic anomaly over the Piedmont pluton along a north-south profile across the center of the anomaly.

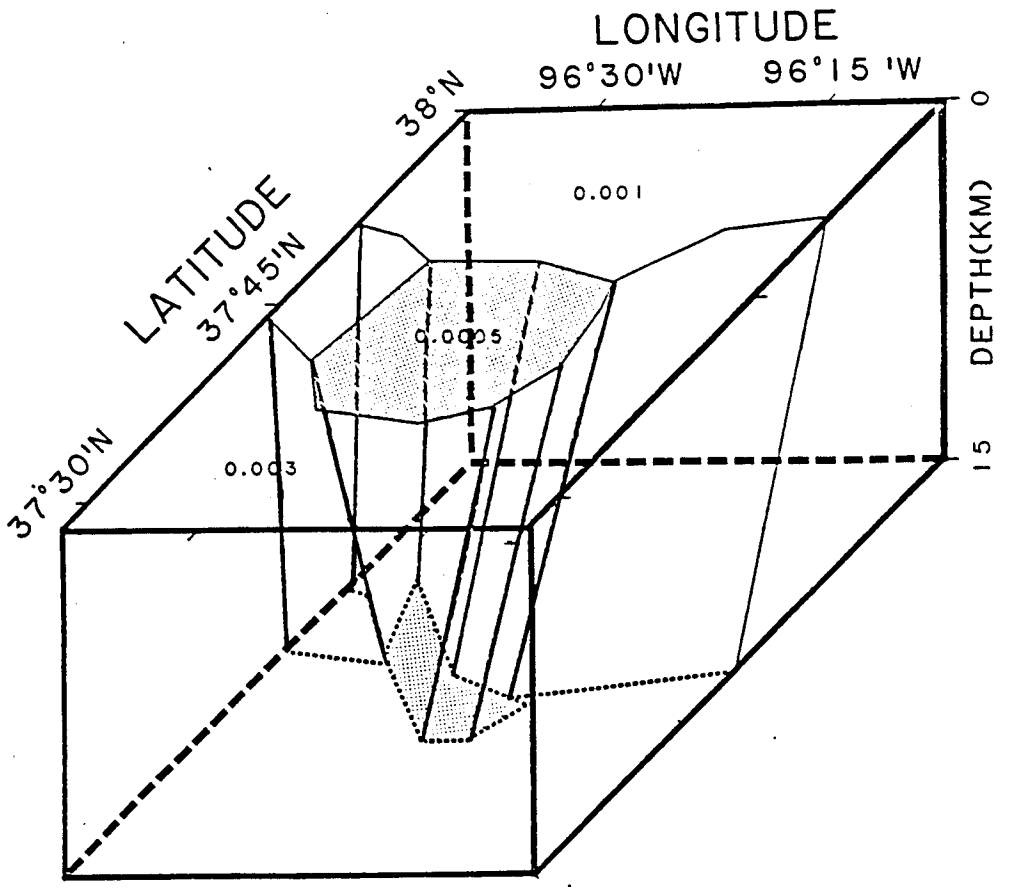

Figure 38. Block diagram of bodies used to three dimensionally model the Piedmont pluton. Solid lines are the top edges of the bodies and small dashed lines are the bottom edges of the bodies. Dotted pattern indicates the bottom and top of the Piedmont pluton. Susceptibilities are emu/cc.

magnetic data versus the three dimensionally modeled magnetic data along a north-south profile over the center of the anomaly. This model has a very good fit of the gradients and the low itself. The Piedmont pluton shown in Figure 38 has a nearly nil susceptibility and inwardly-dipping to nearly-vertical sides. The low susceptibility body to the north of this pluton may be a mixture of scattered granites, metaigneous, and metasedimentary rock as evidenced by the drill hole data (Figure 4).

Significance of the Models

The potential field models in the eastern Wichita Magnetic Low obtained by two-and-one-half gravity and magnetic and three dimensional magnetic modeling have produced geologically significant results. The generally subtle gravity anomalies and correspondingly small density contrasts make integrated modeling difficult and ambiguous, however, the two-and-one-half dimensional gravity and magnetic models are consistent with the observed geological and geophysical data in the area. In a general sense, these models show that these data can be modeled by assuming that two distinctly different crustal blocks are juxtaposed in the area of the Wichita Magnetic Low. The long wavelength component of the magnetic low reflects the magnetic effect caused by the high susceptibility contrast

and edge effect between the upper and lower crust across this crustal boundary. Felsic intrusives cannot solely explain the long wavelength component of the magnetic minimum. This is supported by the lack of large, correlative gravity anomalies. The subtle regional gravity anomaly across this crustal boundary is reflected by the small density contrast between the two crustal blocks in the lower crust and the density contrast produced by the southerly-dipping Moho. The 45o southerly-dipping suture model is believed to be the best model in the area of study because it explains the gravity gradient in southeastern Kansas and also best approximates the magnetic low in the eastern part of the Wichita Magnetic Low.

The large susceptibility contrast and edge effect between the crustal blocks produces the regional east-west magnetic low which transects the state of Kansas. The discontinuous nature of this regional, linear minimum can be explained by laterally-varying susceptibility contrasts and by interference effects due to emplacement of sources after the collisional event. The lack of a correspondingly prominent gravity anomaly along the boundary of this suture indicates that the two crustal blocks have fairly similar densities along this suture zone.

Nearly non-magnetic plutons result in a short wavelength component superimposed on the longer wavelength component due to the susceptibility contrast across the two

magnetic terranes. These plutons alone can not explain the regional magnetic low. The steep gradient on the south of the Wichita Magnetic Low is modeled by a large susceptibility contrast between the steep-sided, shallow, Piedmont pluton and the high susceptibility crust. The low susceptibility body to the north of the Piedmont pluton is interpreted as a volume of metasedimentary rocks and felsic rocks. The east-west trend of these metamorphic rocks (Figure 4) may be indicative of a remnant metamorphosed sedimentary wedge associated with a pre-collisional continental margin.

The lack of gravity minima over the Graniteville-type plutons in the Wichita Magnetic Low is also reported in the St. Francois Mountain terrane in southeast Missouri by Cordell and Knepper (1987). Nearly half of the identified tin-granite (Graniteville-type) plutons in the St. Francois Mountain area lack correlating magnetic and gravity lows, Cordell and Knepper (1987) cite possible reasons for the absence of gravity minima as due to different densities of the plutons, varying densities within the host rock, and variable depth extents of the plutons.

Figure 39 is a two-dimensional schematic diagram of the general geological interpretation of the crust across the eastern end of the Wichita Magnetic Low along 97°W as discerned from the gravity and magnetic modeling and geological data. This interpretation shows that the entire

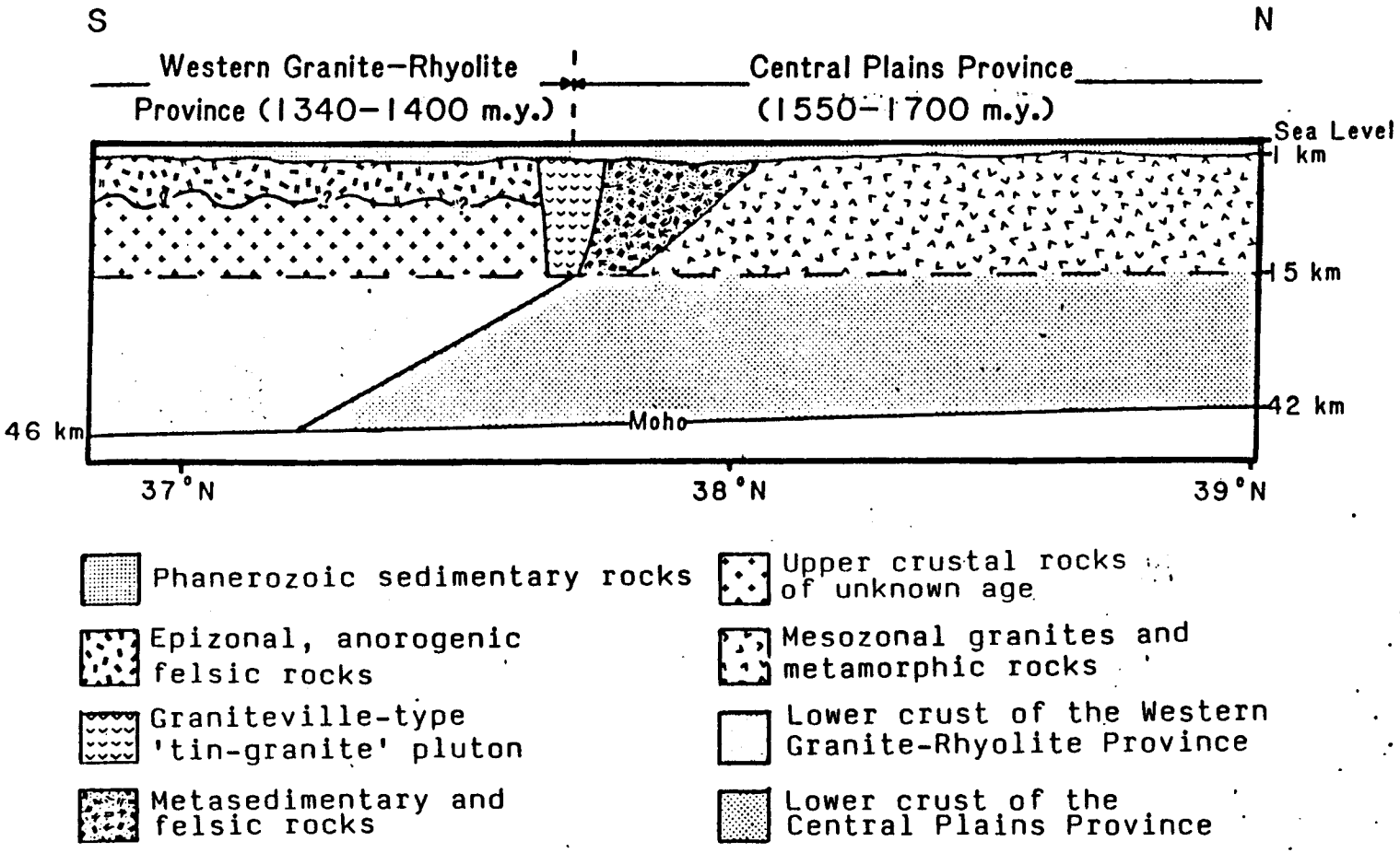

Figure 39. Schematic diagram of the general geologic interpretation of the crust along 97o as determined by potential field modeling and geological data.

crust is involved. The Central Plains and Western Granite-Rhyolite Provinces are separated in the upper crust by a Graniteville-type, tin-granite, pluton and a metasedimentary/felsic rock wedge to the north. The relationship of the epizonal, anorogenic felsic rocks of the Western Granite-Rhyolite Province with the underlying rock is uncertain, because the contact between the anorogenic felsic rocks and the speculated underlying upper crust has not been established. A southerly-dipping to nearly vertical suture boundary between the major crustal blocks is interpreted. The relationship between the suture zone and the Graniteville-type plutons is not known. Gay (1984) reports that granite in the western part of the Wichita Magnetic Low yielded an age of 1380 m.y. This age is comparable to the earliest dates obtained in the anorogenic terrane to the south. The Graniteville-type plutons in the Wichita Magnetic Low could be delineating the trend of the suture zone as these bodies may have been emplaced along this crustal zone of weakness. Alternatively, these bodies may have been emplaced prior to or during the collisional event.

The higher susceptibility, slightly denser, and thicker crust to the south of this crustal boundary is consistent with the regional magnetic and gravity maps. These results are similar to those found in modeling gravity data over proposed Proterozoic sutures in Canada. Gibb et al. (1983)

have noted that in all of the modeled sutures in Canada, the thicker and denser crust occurs in the younger terrane, although no reason for this seemingly significant observation is given.

A problem with identifying this feature as a suture zone is that the southern terrane (Western Granite-Rhyolite terrane of Bickford et al., 1986) is overlain by younger anorogenic granites and rhyolites, and little is known of the underlying, presumably older basement (Bickford et al., 1981; Denison et al., 1984; Thomas et al., 1984; Nelson and DePaulo, 1986). Starich (1984) proposed that the southern terrane contains significant amounts of highly magnetic lower crust which may be a differentiated residuum of the anorogenic crustal melting episode which buried this terrane with shallow felsic equivalents. Sampling and dating of the hypothesized older crust below the anorogenic rhyolites and granites would greatly aid in interpreting the nature of this terrane. Another problem of identifying this zone as a suture is that there has not been any remnant oceanic crust or ophiolites reported. This could be due to 1) a lack of drill hole information along this magnetic low, 2) an erosional event which completely erased the record of any oceanic crust or 3) Proterozoic tectonic processes were different than those in the Phanerozoic. However, the evidence suggests that this linear magnetic low separating the two distinct Precambrian terranes may be

modeled as a feature which involves the entire crust. This implies that an interpretation of this feature as a suture is possible, but it does not conclusively confirm that it is a suture zone.

VI. CONCLUSIONS

Yarger (1981) proposed that the negative magnetic lineament in Kansas is related to a suture zone. The terrane to the north of this proposed suture zone is characterized by regional gravity and magnetic lows as seen in regional maps and MAGSAT data, relatively thinner crust, and lower average crustal velocities than the southern terrane. Several magnetic and gravity anomalies striking into this zone are greatly attenuated or terminated at this boundary. The most prominent magnetic low along this series of east-west trending negative magnetic anomalies is the Wichita Magnetic Low in southeastern Kansas. Locally within this broad low, a series of discrete oval-shaped magnetic lows with encircling highs corresponds with nearly non-magnetic, tin or two-mica, Graniteville-type granites. These distinct east-west trending magnetic minima lack prominent gravity anomalies.

Magnetic and gravity data sets were compiled for the area over the Wichita Magnetic Low in southeastern Kansas. Isolation and enhancement techniques reveal that the long wavelength east-west component of the Wichita Magnetic Low is observed in the 10 km upward continued magnetic data and is reflected in the 10 km upward continued gravity data as

subtle truncations and attenuations of gravity anomalies. Short wavelength, magnetic minima are not correlatable with gravity minima except in the eastern part of the Wichita Magnetic Low.

Two-and-one-half dimensional gravity and magnetic modeling across the Wichita Magnetic Low shows that this feature can be modeled as the combined effect of a suture zone and Graniteville-type granitic plutons. The source of this magnetic minimum cannot be reasonably modeled as being solely due to a suture or non-magnetic plutons. The subtle gravity anomalies are reflected as small density contrasts between the major crustal blocks in the lower crust and by local sources in the upper crust. The steep gradient along the southern margin of the Wichita Magnetic Low is modeled as a result of a large susceptibility contrast between upper crust of the southern terrane and nearly non-magnetic granitic plutons. The timing of the emplacement of the granitic plutons within the Wichita Magnetic Low is unknown, however, the east-west trend of these low susceptibility bodies suggests this was an area of crustal weakness. The significance of the modeling is that it indicates the entire crust is involved, thus a suture is highly probable.

The three dimensional magnetic model of the Piedmont anomaly suggests that an inward-dipping to vertical-sided, nearly non-magnetic pluton extending from the Precambrian

basement-sedimentary rock interface to midcrustal depth satisfies the observed magnetic data. The observed data and models thus suggest that a buried east-west trending, southerly-dipping, Proterozoic suture zone occurs along this magnetic low. The prominent Wichita Magnetic Low is a result of the contrast between these two different crustal blocks and large, Grantiteville-type, granitic plutons.

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