

Lithological Distribution in the Basement of Kansas, Based on Potential-Field Data

GM2.8

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SUMMARY

A map of lithological distribution in the Precambrian basement in Kansas is presented. The map is based upon the density and magnetization distributions within a specific layer as calculated by the inverse approach presented by Xia and Sprowl (1992), and on well data. The depth to the top of the layer is determined from the digitized topographic map of the Precambrian basement (Cole, 1976) constrained by additional well data (Cole and Watney, 1985). The thickness of the upper Precambrian layer is determined by trial-and-error such that the calculated density/magnetization models show reasonable correspondence with known geology. Rock-type boundaries are determined visually, consistent with the potential fields and well data.

INTRODUCTION

Phanerozoic rocks cover virtually all of the Precambrian basement in Kansas, except for a large inclusion of Precambrian granite are found in Cretaceous mica peridotite at Rose Dome in Woodson County (e. g., Bickford, et al., 1971). Cole (1976) published a contour map of the top of the Precambrian rocks. There are more than 3,400 wells drilled to the Precambrian basement in Kansas (Cole and Watney, 1985). Most of them are located in the Central Kansas Uplift and Nemaha Uplift regions. The thickness of the Phanerozoic rocks changes from more than 3,000 m (9,840 ft) in Meade County of southwestern Kansas to less than 200 m (660 ft) in the Nemaha Uplift of northeastern Kansas. Based on well cuttings and limited core data, Bickford et al. (1981) presented a map of basement rock types in Kansas.

The Midcontinent Rift System (MRS) in Kansas (e. g., Bickford, et al., 1981; Berendsen, et al., 1988), a north-northeast -- south-southwest oriented feature, is the only Precambrian structural high clearly reflected in gravity and magnetic anomalies. The MRS is an areally extensive rift basin characterized by extensive intrusive and extrusive volcanism followed by and/or interspersed with immature clastic sedimentation (Berendsen, et al., 1988).

More than 59,000 gravity-station measurements and approximately 72,000 line-km (45,000 line-mi) of digitally recorded aeromagnetic data are available at the Kansas Geological Survey. These potential-field data provide useful information about the Precambrian basement and the Moho discontinuity in Kansas. Lam (1986) used filtering methods to systematically study the Bouguer anomaly. Lam and Yarger (1989) discussed the major features of the Bouguer gravity map. They showed that there are two predominant lineations in the gravity data. One is N40E, associated with the MRS, and the other is N45W, probably due to pre-rift fractures that for some reason were closely aligned. Yarger (1983, 1985) used filtering techniques to study the Kansas basement based on aeromagnetic data. He showed the MRS does not terminate in central Kansas but continues along a south-western trend to at least the Kansas-Oklahoma border. He also pointed out a distinct east-west trending boundary across central Kansas between the 1,600-1,700 Ma mesozonal granitic terrane to the north and a younger, about 1,400 Ma epizonal granitic terrane to the south. Two-dimensional geophysical models of the MRS were constrained by potential fields and seismic data (Yarger, 1989; Lam and

Yarger, 1989; Somanas et al., 1989; and Woelk and Hinze, 1991). A three-dimensional model of the MRS has also been calculated from gravity data (Xia and Sprowl, 1990).

Steeple (1982) studied the Salina-Forest City interbasin using seismic data and pointed out that the edges of the Salina and Forest City basins should be of economic interest. Microearthquakes results (Steeple, 1982; and Steeples, et al., 1987) indicate that the Humboldt Fault system is still active along a zone 400 km (240 mi) long (north-south) and 50 km (30 mi) wide (east-west) coincident with the Nemaha uplift from southeastern Nebraska to north-central Oklahoma. Miller (1983) used earthquake seismograms to study the crust in Kansas and postulated the presence of several anomalous velocity areas in the crust of eastern Kansas.

An objective of this study is to invert residual potential-field data (408 by 205 gridded points, Xia, 1992) to density/magnetization distribution within the Precambrian basement by the approach developed by Xia and Sprowl (1990, 1992) and to develop a model of rock types based upon the inverse results and the known geology. The computer program is given by Xia (1991). The inversion is constrained by results from well data (Cole, 1976; Cole and Watney, 1985; and Berendsen et al., 1988) and the known geology (Steeple and Bickford, 1981; and Bickford, et al., 1981).

ANOMALIES DUE TO THE RELIEF OF THE BASEMENT

We assume the residual magnetic anomaly and the residual gravity anomaly are mainly caused by two kinds of geological sources: the topographic relief of the Precambrian basement and the lithological change in the Precambrian basement rocks. The topography of the top of the Precambrian rocks in Kansas (Cole, 1976) was digitized. The depth to the Precambrian rocks is modeled by the digitized map and 3,400 points of well data (Cole and Watney, 1985). In order to model potential-field anomalies caused by this physical interface, we assume the rocks of the Precambrian basement to be mostly granitic, the average density of the basement was chosen as 2.70 g/cm³ (Garland, 1979, p. 189). The rocks above the basement are primarily shale, limestone and sandstone and the average density of these rocks is 2.43 g/cm³ (Garland, 1979, p. 189) if the thickness of each is the same. Therefore, the density contrast of the interface would be 0.27 g/cm³ (= 2.70 - 2.43). We also assume that the granitic rocks in the basement contain one percent magnetite with an effective susceptibility of $k = 0.25$ (CGSM unit) magnetized by the Earth field of $H = 0.5$ Oe, giving an intensity of magnetization of approximately $M = Hk = 0.5 \times 0.01 \times 0.25 = 125$ nT (or $125 \times 10^{-9} / 4\pi \times 10^{-7} \cong 0.1 A / m$). This is an order-of-magnitude figure for polarization of basement rocks commonly used in magnetic model calculations (Nettleton, 1976, p. 362-363). Because sedimentary rocks are usually nonmagnetic, we use 125 nT as the magnetization in modeling the magnetic interface. The inclination and declination of the magnetization are 65 degrees and 7 degrees, respectively. Given these physical parameters, the calculation of the modeled anomalies due to the topographic relief of the Precambrian basement is straight-forward.

The magnetic anomaly caused by the topographic relief of the Precambrian basement has an amplitude of around 200 nT and is subtracted from the residual magnetic anomaly. The gravity anomaly caused by the topographic relief of the

Precambrian basement has an amplitude of around 22 mGal, and is subtracted from the residual gravity anomaly (Xia, 1992). We assume the remaining potential-field anomalies, which will be inverted in following sections, are due to the lithological variability in the basement.

MAGNETIZATION DISTRIBUTION IN THE BASEMENT

We initialize the magnetization of the upper Precambrian layer to 125 nT. The inclination and declination of magnetization are chosen as 65 degrees and 7 degrees, respectively. The top surface of the layer is defined by the digitized map of the top of the Precambrian rocks in Kansas (Cole, 1976) and well data (Cole and Watney, 1985). The bottom surface of the upper Precambrian layer is constrained to be parallel to the top surface. The thickness of the layer is determined by the trial-and-error method. The criterion is that magnetization distribution within the layer defined by these two surfaces should be acceptable by comparing with the geological information. The thickness of the upper Precambrian layer finally determined is 6 km.

The initial root-mean-square errors (*RMS*) is 185 nT and the maximum deviation (*MAXD*) 999 nT. Twenty iterations reduce the *RMS* errors to 13 nT (1.3 % of the maximum real anomaly) and *MAXD* 67 nT. The calculations took 3,600 CPU seconds on a Data General MV20000. The final result, which represents the magnetization distribution within basement rocks, is shown in Figure 1.

DENSITY DISTRIBUTION IN THE BASEMENT

The top surface of the layer is the same as the magnetic case shown in the above section. The bottom surface of the layer is again constrained as parallel to the top surface. The thickness of the layer is chosen by the trial-and-error method. The thickness finally determined is 2.7 km. The density distribution within the layer defined by these two surfaces is acceptable by comparing with the known geology. We initialize the density of the layer to 2.67 g/cm³ (in this case, it is the same as to initialize the density contrast to 0, then add 2.67 g/cm³ to the final result of the inversion).

The initial *RMS* error and *MAXD* are 11.7 mGal and 50.8 mGal, respectively. After ten iterations, *RMS* is reduced to 0.1 mGal (less than 0.2% of the maximum real anomaly), and *MAXD* is reduced to 3.5 mGal. The calculations took 250 CPU seconds on a Data General MV20000. The calculated density distribution is shown in Figure 2.

POSTULATED ROCK TYPES IN THE BASEMENT

Density and magnetization are weak links between potential-field data and geology because different rocks can have the same density and/or magnetization. This property makes interpretation of potential-field data difficult. On the other hand, lithologic contrast usually provides contrast in density and magnetization. Therefore, knowledge of the density or magnetization distribution within a given layer contains information about subsurface geology. It is possible to infer the subsurface geology through an appropriate mapping process. We try to map the density and magnetization distributions to rock types in the basement with the help of the known geology.

Some relationships between density/magnetization distribution and basement rock types can be "finger-printed" by visually comparing the magnetization and density distribution maps (Figures 1 and 2) with the known basement rock types (Bickford et al., 1981; Yarger, 1983, 1985). Statistically, we can segregate granites, basalts (gabbro), and sedimentary rocks based on density (Carmichael, 1989, p. 163). Based on these criteria, we summarize the mapping conditions in Table 1, which allow us to determine the rock types in the basement.

Figure 3 shows the postulated basement rock types in Kansas. It clearly shows the MRS trend (gabbro) down to almost Kansas-Oklahoma border and the distinct boundary between north and south granitic terranes. It also shows the location of granitic plutons, which contain about 2% of magnetite by weight (Steeple and Bickford, 1981).

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Table 1. Mapping conditions from potential fields to rock types.

Rocks	Density (g/cm ³)	Magnetization (nT)
Gabbro	> 2.80	
Sandstone	< 2.35	
Mesozonal Granite	2.35 -- 2.65	< 150
Epizonal Granite	2.35 -- 2.65	150 -- 300
Rhyolite	2.65 -- 2.80	200 -- 275
Metamorphic Rocks	2.30 -- 2.80	275 -- 350
Granitic intrusion	2.30 -- 2.80	> 350

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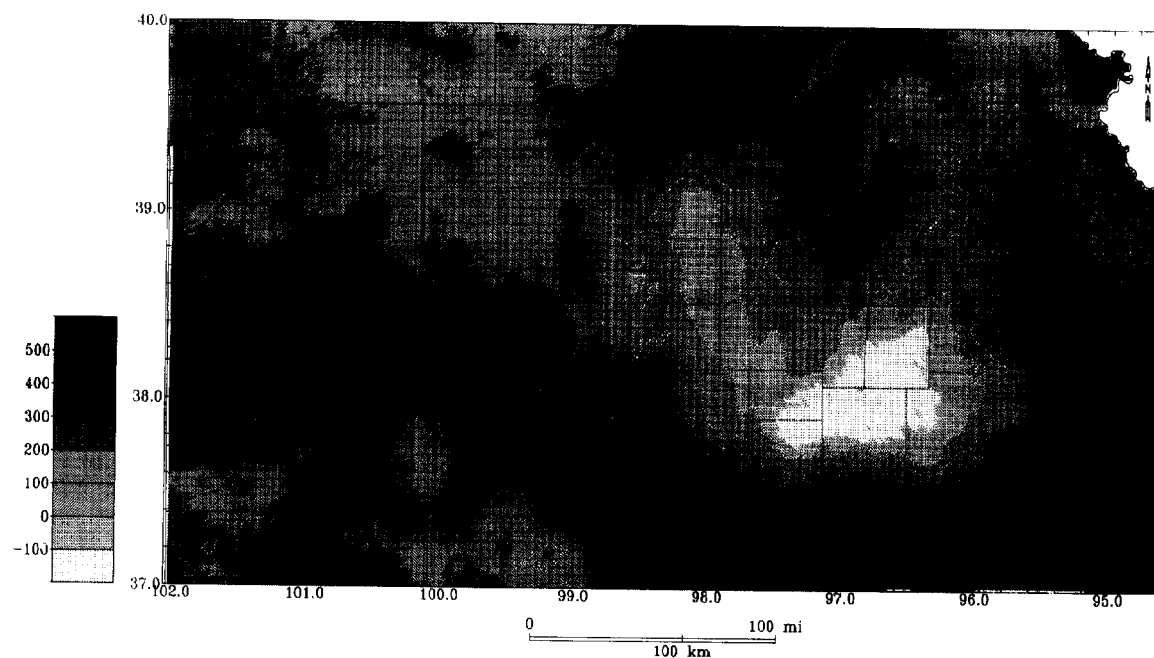


Figure 1. The magnetization distribution in the Precambrian basement. Shading interval is 100 nT. Coordinates in x and y directions are degrees of longitude and latitude, respectively.

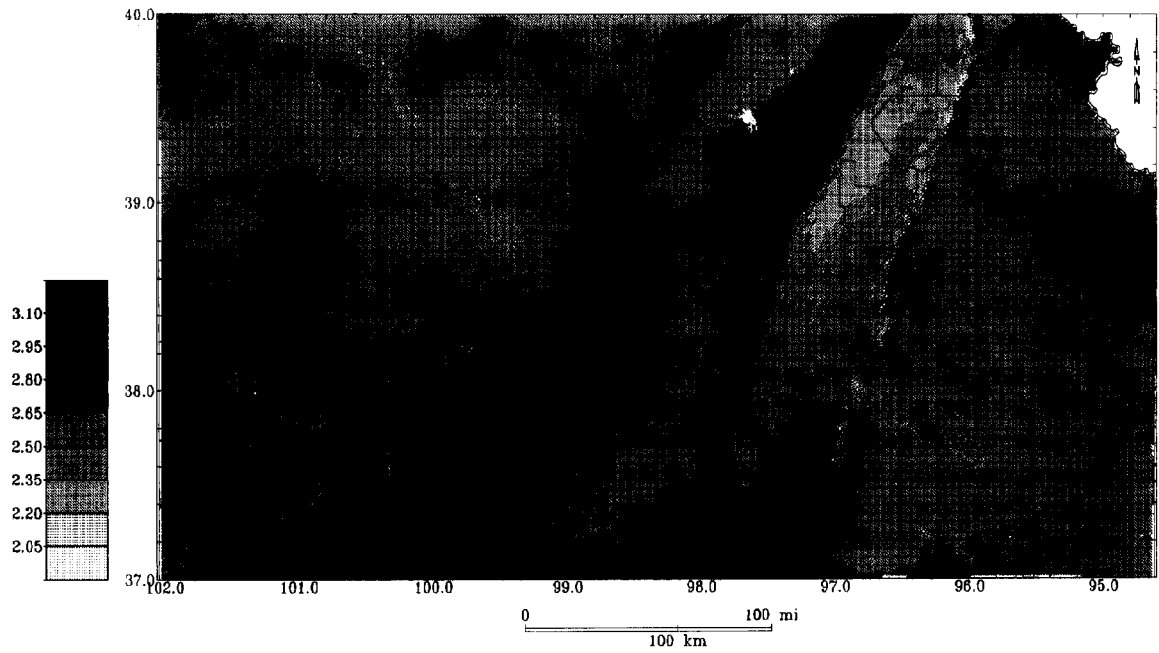
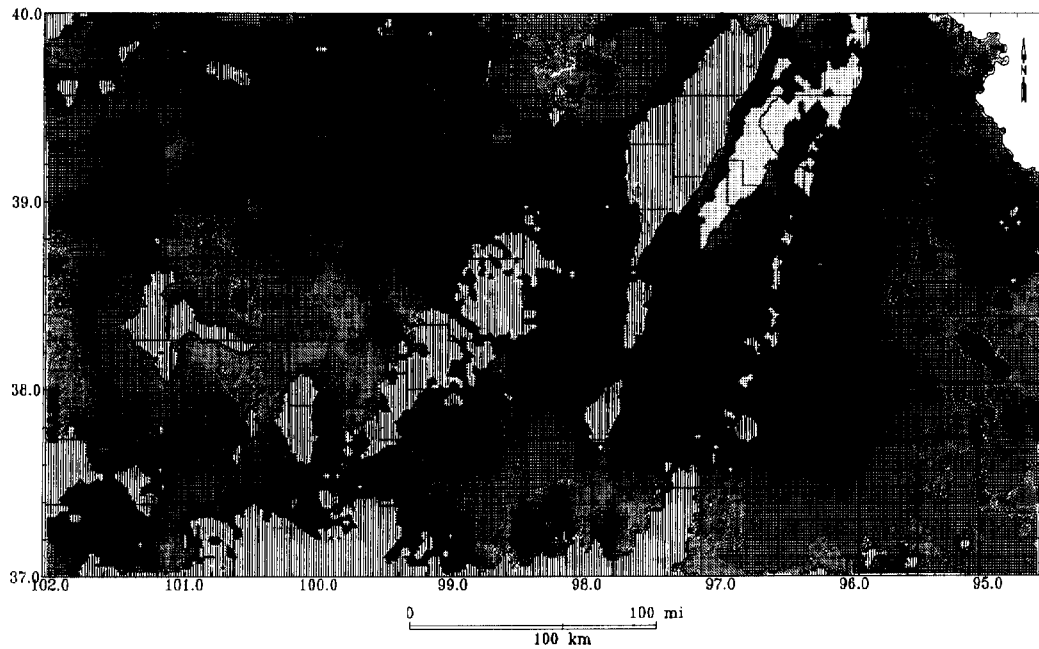


Figure 2. The density distribution in the Precambrian basement. Shading interval is 0.15 g/cm³. Coordinates in x and y directions are degrees of longitude and latitude, respectively.



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|  | Gabbro |  | Sandstone |  | Rhyolite |  | Metamorphic Rocks |
|  | Epizonal Granite |  | Mesozonal Granite |  | Granitic Intrusion | | |

Figure 3. Postulated rock types in the basement of Kansas, based on inversion of potential-field data. Coordinates in x and y directions are degrees of longitude and latitude, respectively.