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A GEOPHYSICAL STUDY OF BASEMENT STRUCTURE IN NORTHEASTERN NEW MEXICO

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INTRODUCTION

The Precambrian basement in northeastern New Mexico (Foster et al., 1972; Roberts et al., 1976) is dominated by structures associated with the ancestral Rocky Mountains which are widely believed to be the result of the same tectonic event that produced the Ouachita–Marathon orogenic belt (e.g., Kluth and Coney, 1981). Although there is much disagreement regarding the nature of Late Paleozoic plate interactions along the southern margin of North America which resulted in the development of this orogenic belt (e.g., Keller and Cebull, 1973; Wickham et al., 1976; Dickinson, 1981; Pindell and Dewey, 1982), activity along an irregular continental margin can explain many of the observed variations in timing (Kluth and Coney, 1981).

In the study area (Fig. 1), this Pennsylvanian and Permian tectonic activity produced positive areas, the ancestral Rocky Mountains (Apishapa uplift, Sierra Grande uplift, Bravo dome, Pedernal uplift, Central Basin platform), separated by troughs in which large quantities of sediments accumulated. Late in Early Pennsylvanian time, deformation spread northwestward from the eastern portion of the Ouachita–Marathon orogenic belt, and by Middle Pennsylvanian time the ancestral Rocky Mountains reached their greatest extent. Late in the Middle Pennsylvanian, tectonic activity began to spread southward in New Mexico, and, as a result, the Pedernal uplift was raised to a level sufficient to provide feldspar-rich sediments to the adjoining basins. Structural activity continued at a gradually slower rate throughout Late Pennsylvanian and Early Permian time. In latest Pennsylvanian or Early Permian time, the Central Basin platform and the Diablo platform in west Texas were rapidly uplifted, the Pedregosa basin rapidly subsided, and the Delaware and Orogrande basins reached maximum development (Kluth and Coney, 1981).

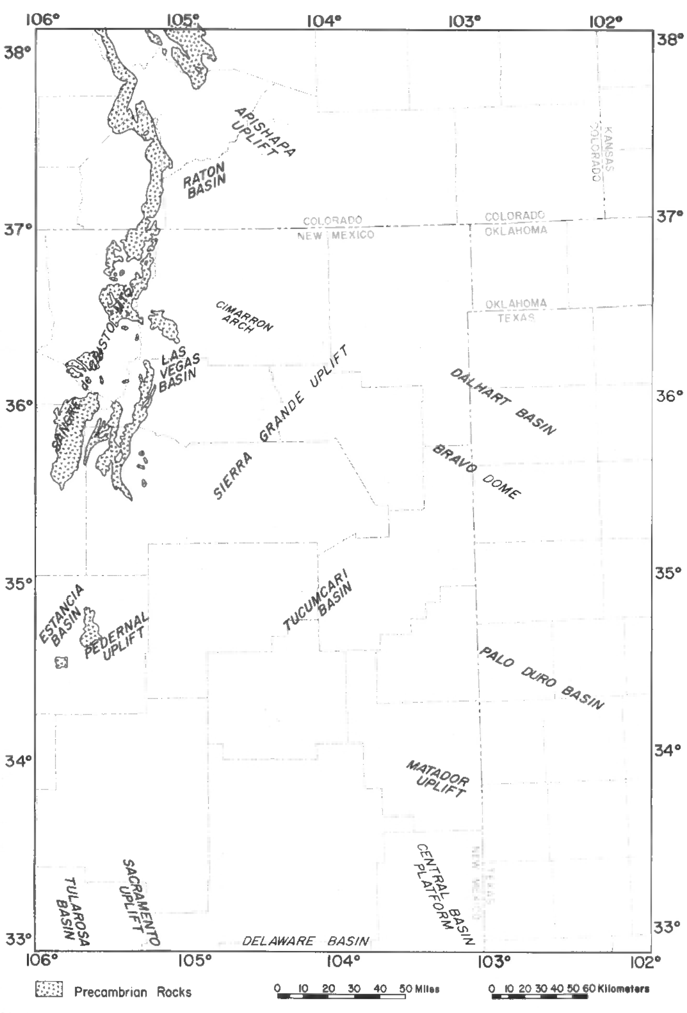

FIGURE 1. Location map of the study area.

The Laramide orogeny was another major phase of tectonic activity which affected the Precambrian basement of northeastern New Mexico. This orogenic activity is thought to have been confined to latest Cretaceous through latest Eocene time (80 to 40 m.y. ago; Coney, 1976). The major Laramide uplifts and basins of the Rocky Mountain foreland were developed in a stress field of regional compression while the North American plate was drifting westward over an eastward-dipping subduction zone (Woodward, 1976). The major effect of this orogeny in northeastern New Mexico was to form uplifts with at least a minor amount of eastward-directed overthrusting (e.g., Sangre de Cristo Mountains).

Middle and late Cenozoic activity in the area has been confined to uplift (e.g., Sangre de Cristo Mountains, Sacramento uplift), basin formation (e.g., Tularosa basin), volcanism associated with the Rio Grande rift (e.g., Chapin, 1971; Kelley and Duncan, 1985) and volcanism along the Jemez lineament.

Working with colleagues at the U.S. Geological Survey and various universities (most notably the University of Texas at Dallas and the University of Wyoming), we have been collecting gravity data in New Mexico for nine years. These efforts have resulted in published complete Bouguer anomaly maps of the Rio Grande rift (Cordell et al., 1982) and of New Mexico (Keller and Cordell, 1983). For this study of the area shown in Figure 1, we have added to the data base used to produce these maps, resulting in the gravity-station distribution shown in Figure 2.

GRAVITY DATA

A complete Bouguer anomaly map was produced, but is not significantly different from the map of Keller and Cordell (1983). However, a strong west-to-east increase in gravity values (~100 mgal) obscures many anomalies of interest. This increase is largely due to deep lithospheric structure (Keller et al., 1979).

In order to remove this regional trend, a fifth-order polynomial surface was chosen as approximating the regional gravity field over the study region. Gravity values on this surface (Fig. 3) generally increase in a regular manner from the northwest to southeast. This increase is a result of a major density change in the mantle lithosphere as evidenced by a change in Pn velocity from 7.6 km/s to 8.2 km/s (Keller et al., 1979).

Residuals with respect to this surface (Fig. 4) provide a better definition of upper crustal features which are of interest in this study. A series of generally north–south-trending, negative gravity anomalies are located in the northwestern portion of the map. The southern of these anomalies is related to the Las Vegas basin, while the northern anomalies are related to the Raton basin. As discussed by Cordell and Keller (1984), Precambrian outcrops partially overlie these anomalies, suggesting the basins extend beneath these outcrops.

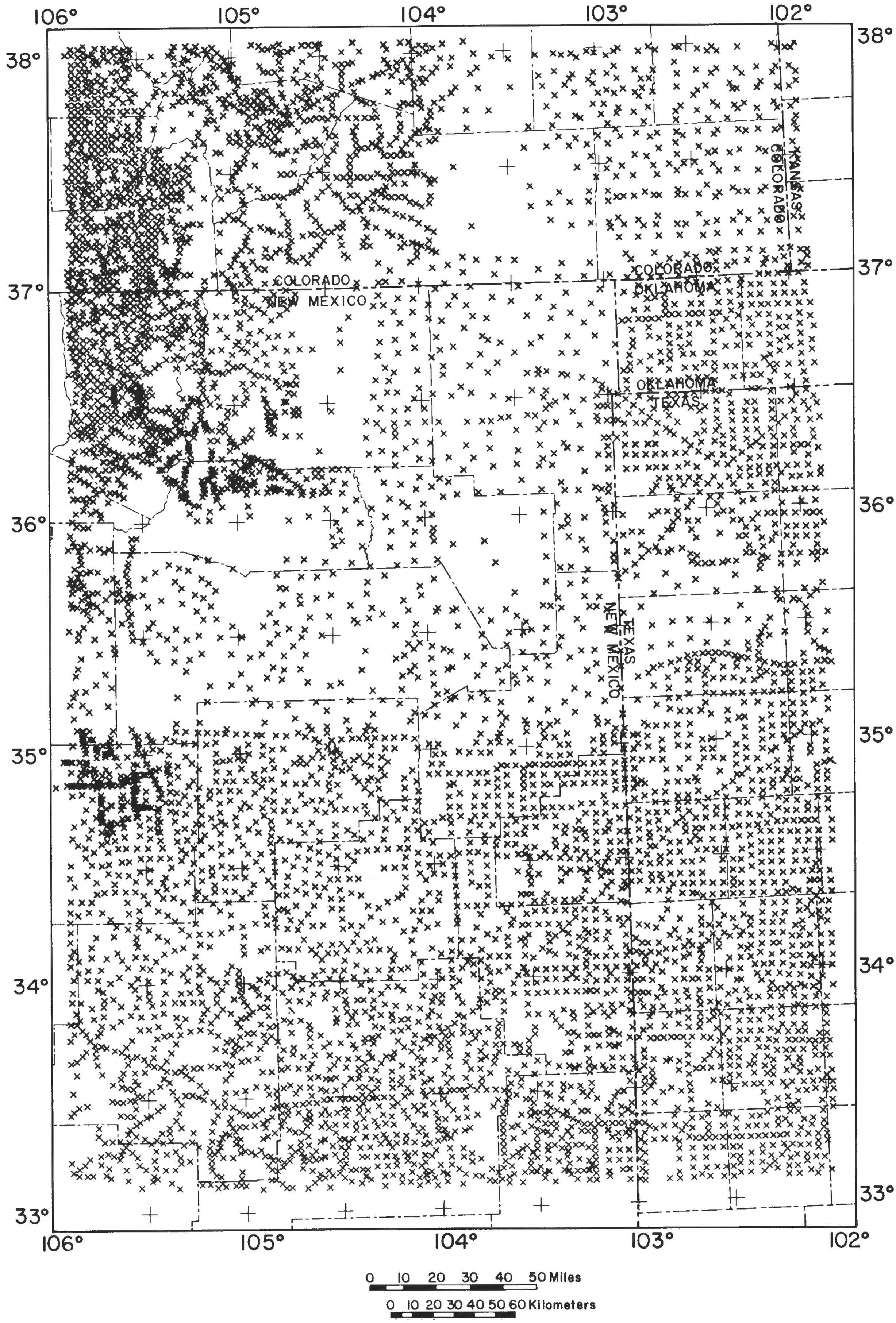

FIGURE 2. Distribution of gravity stations used in this study.

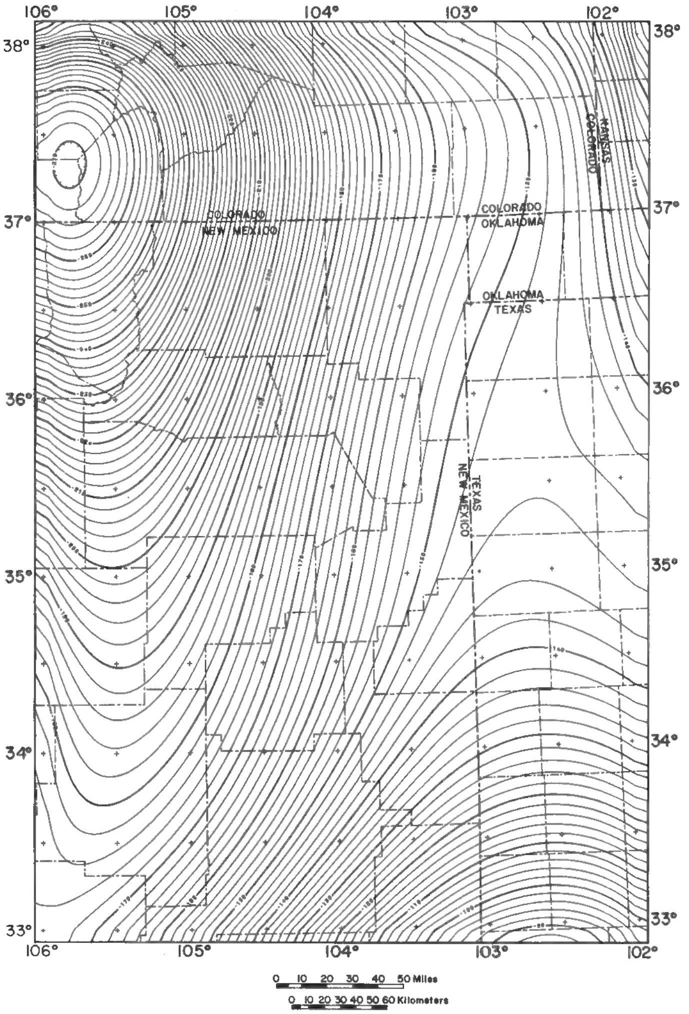

FIGURE 3. Fifth-order polynomial surface map which was fitted to the complete Bouguer gravity anomaly values. This surface was chosen as approximating the regional gravity field over the study area. Contour interval = 2 mgal.

The second prominent features of interest are the east–west-trending gravity lows located just south of 35°N latitude. These anomalies are related to the Tucumcari and Palo Duro basins and seem to trend to the south as they reach about 105°W longitude. South of approximately 34.5°N latitude, these anomalies could indicate the presence of a previously unknown basin.

The Pedernal uplift is defined by positive anomalies located at about 105.5°W longitude and 34.5°N latitude. The eastern limit of the Estancia basin is defined by negative values west of the Pedernal uplift.

The Bravo dome (Oldham nose) is defined by a prominent, NW–SE-trending, positive anomaly located along the Texas–New Mexico border at about 35.5°N latitude. This anomaly intersects a NE–SW trend at 104°N longitude which is associated with the Sierra Grande uplift. The NW–SE-trending anomaly is probably due to a deep crustal feature related to the southern Oklahoma aulacogen because it is too large to be realistically due to simple basement relief. To the north of the Bravo dome, negative anomalies define the western portion of the Dalhart basin.

The Sacramento uplift, which is located in the southwestern corner of the area of study, produces positive anomalies.

MAGNETIC DATA

An aeromagnetic map of New Mexico has been compiled recently by Cordell (1983). A portion of his digital data base has been low-pass filtered and is shown in Figure 5. This low-pass filtered map can be displayed at page size and is more compatible with the gravity maps.

Aeromagnetic-anomaly values primarily reflect variations in the concentration of magnetite. In this study, magnetic anomalies are mostly related to the Precambrian basement except in three areas where Tertiary granitic intrusions and basalt and basaltic andesite flows are exposed at the surface. In these areas, the contour patterns should be interpreted more carefully due to the effect of these outcrops.

The first region with outcropping igneous rocks is the southwest corner of the study area. This area is characterized by intrusive rocks of various ages (Cretaceous to Miocene). The Sierra Blanca and Capitan Mountains (Sacramento uplift area) represent examples of such intrusive rocks. The second region is the northwest quadrant of the study area. This region is characterized by Tertiary granitic intrusions of the same type as the first region, extrusive rocks which include some sedimentary rocks containing volcanic-rock fragments and basalt and basaltic-andesite flows. The third region is the northeastern corner of the study area which is characterized mainly by basalt and basaltic-andesite flows.

The filtered magnetic map defines a number of significant features and in general correlates very well with the gravity data. However, the magnetic low associated with the Pedernal uplift is puzzling. Perhaps the most noticeable magnetic feature is the NW–SE trend of positive anomalies which begins at the eastern border of the map at approximately 35.5°N latitude. The Bravo dome is located along this trend, and the gravity and magnetic anomalies correlate in this area. Computer modeling of the positive gravity anomaly indicates the presence of a mafic intrusion in the upper crust. Another prominent anomaly this map brings out is the north–northwest-trending high located in the lower left corner of the map, which is paralleled to the east by a similarly trending low. This low correlates with a gravity low and could indicate the presence of a basin in this area. Contours in the southeastern portion of the map are generally broad in accordance with the large thickness of sedimentary rocks in this area. A series of east–west-trending, negative anomalies located at approximately 34.5°N latitude is also well defined. These anomalies are related in part to the Palo Duro and Tucumcari basins and suggest a regional trend of basins at this latitude. The southern part of the Raton basin and the deeper Las Vegas basin to the south are very well defined by negative anomalies which also extend beneath outcropping Precambrian rocks. The western portion of the Dalhart basin is also well defined by the negative anomalies in the northeastern corner of the map.

CONCLUSIONS

Analysis of regional gravity and magnetic anomalies provides a basis for modeling near-surface structures and mapping the Precambrian basement surface where there is an absence of wells drilled to the basement. Although gravity and magnetic methods are similar in many ways, several basic differences exist primarily as a result of the fact that density variations and changes in magnetic susceptibility do not always coincide and that susceptibility is usually more variable than density. Thus, magnetic maps often appear more complicated than gravity maps.

In this study, the various geophysical results were integrated with geological data to produce structural contour maps of the Precambrian basement (Figs. 6 and 7). In a real sense, these figures can be considered major conclusions of this study. Figure 6 is limited in that it qualitatively honors primarily the geophysical data. However, this map extends to areas without well control and shows some interesting areas where well data and geophysical data do not agree. Figure 7 is the presently preferred interpretation because it honors the well data and is based on an integrated analysis of all available data. However, some of the differences between Figures 6 and 7 may represent areas where the well data are misleading with respect to the amount of sedimentary rocks indicated because of basement involved overthrusting and/or intrusions which have been interpreted to be basement.

The previously known basement features are well defined on these maps, which provide contoured interpretations of their nature and extent. In this study, three major questions arise concerning some of these features:

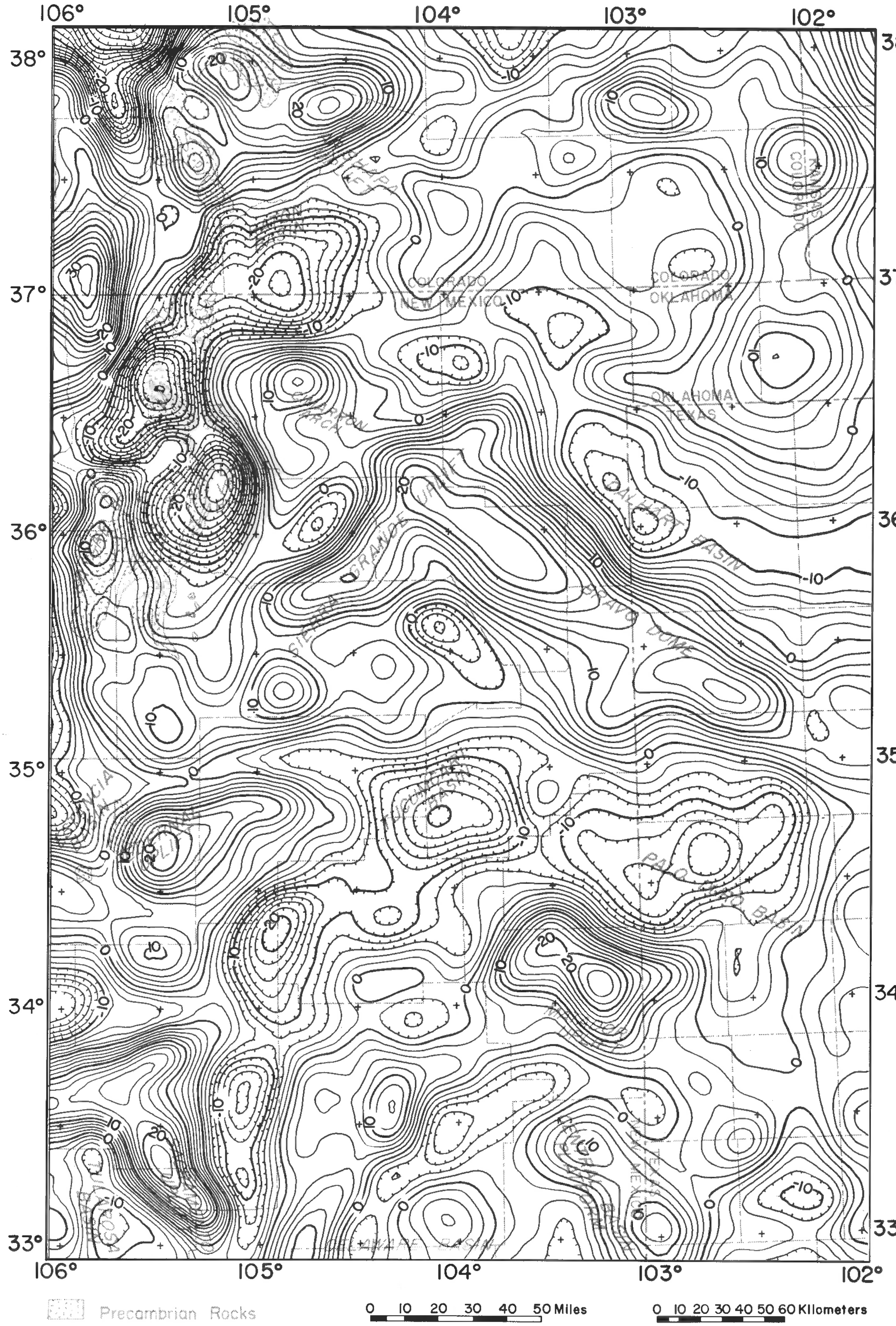

FIGURE 4. Fifth-order residual gravity map. This map was chosen as best defining the upper crustal features of interest in this study. Contour interval = 2 mgal.

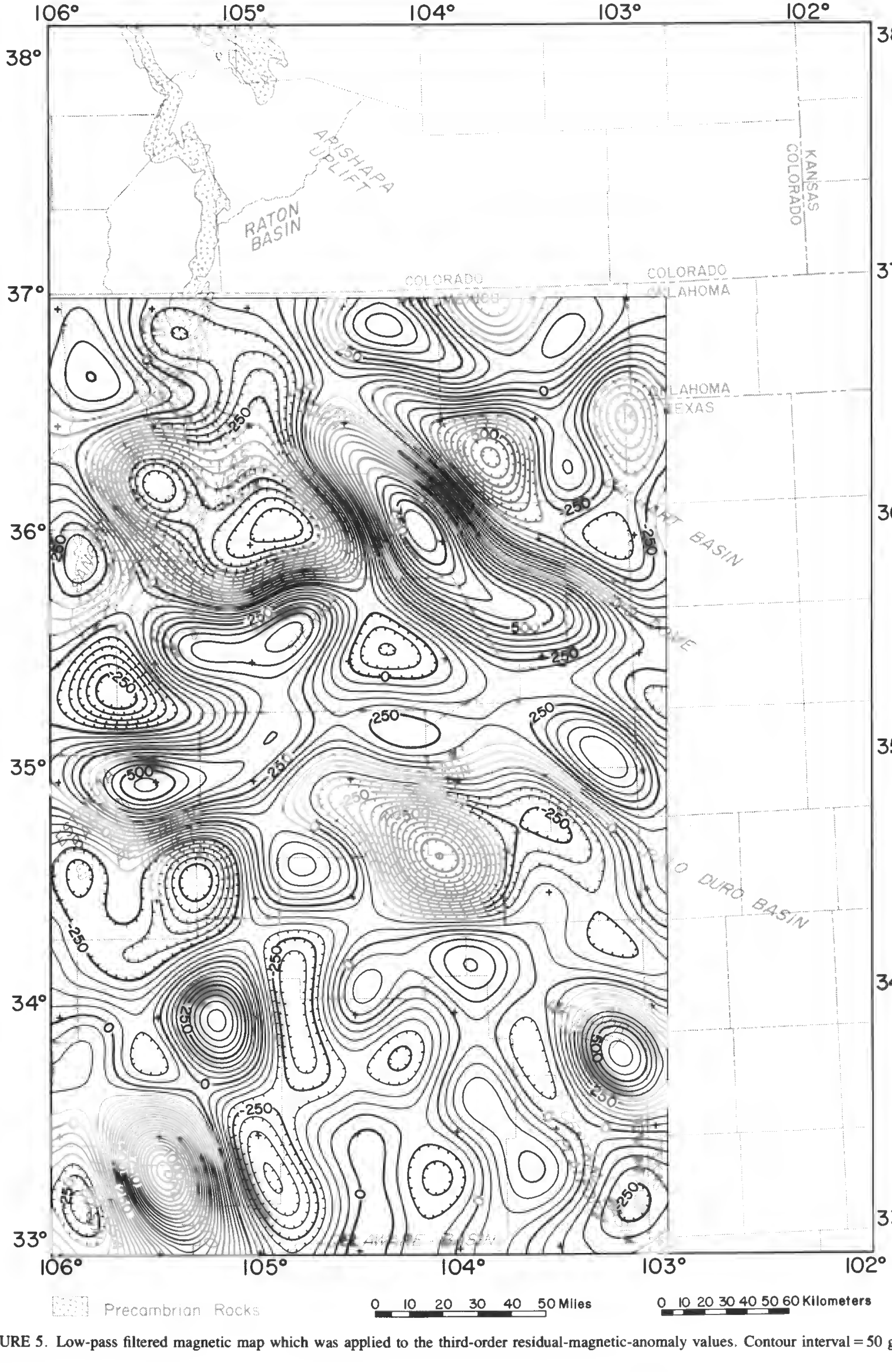

FIGURE 5. Low-pass filtered magnetic map which was applied to the third-order residual-magnetic-anomaly values. Contour interval = 50 gammas.

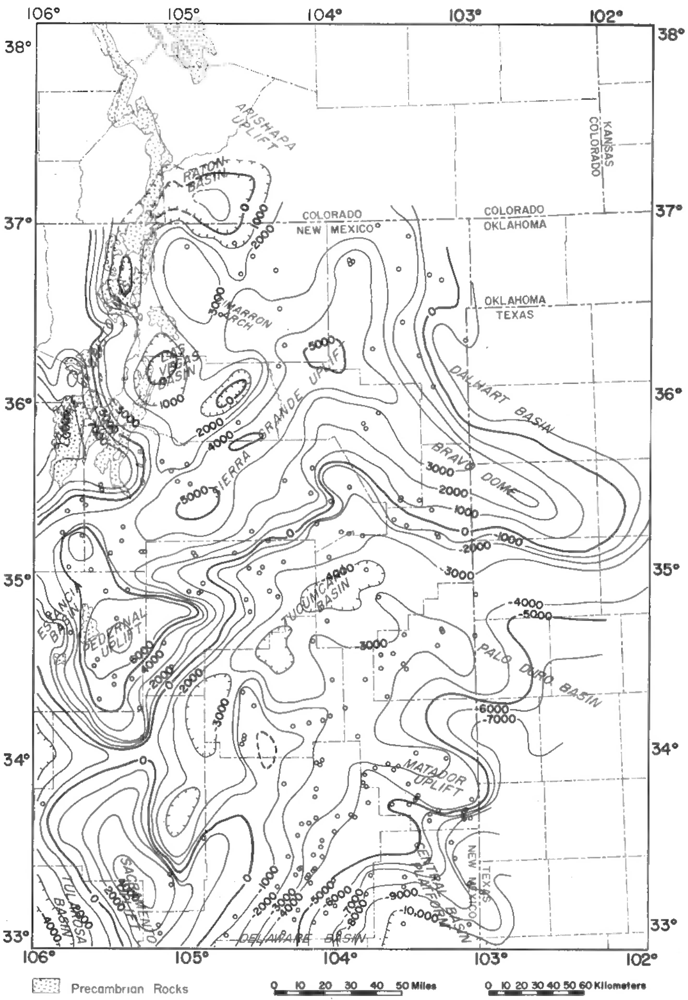

FIGURE 6. Structural contour map of the surface of the Precambrian basement using the various geophysical results of this study in combination with geological data. This map qualitatively honors primarily the geophysical data. It extends to the areas where there is no well control and shows some interesting areas where well data and geophysical data do not agree. Contour interval = 1000 feet.

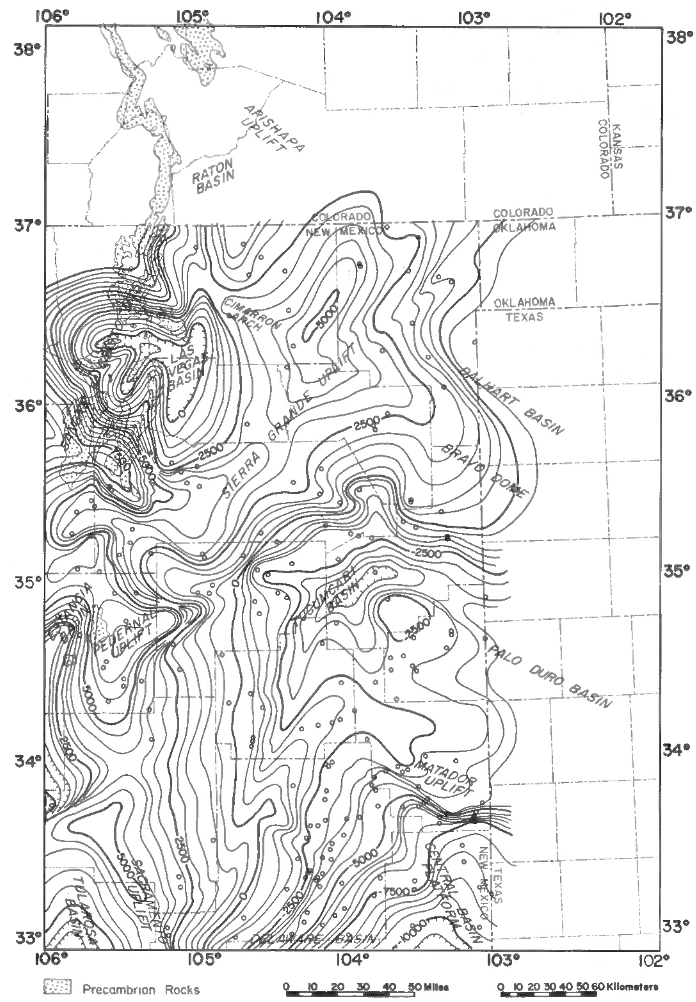

FIGURE 7. Structural contour map of the surface of the Precambrian basement using the various geophysical results of this study in combination with the geological data. This map is the presently preferred interpretation. In constructing this map, we not only honored well data but also integrated the results of this study. Contour interval = 500 feet.

1. Interesting north–south-trending, negative anomalies were found in the southern part of the study area along 105°W longitude. It is reasonable to hypothesize that they represent an extension of the Tucumcari basin or a new basin. Although well data suggest that the Precambrian surface is not deep enough to cause these anomalies, this could be due to the presence of an overthrust sheet or sill-like intrusion which has mistakenly been identified as basement.

2. The positive NW–SE-trending anomalies which represent an extension of the Bravo dome are well defined on the gravity and magnetic maps. These anomalies are probably due in part to a mafic intrusion in the upper crust, which would suggest that relating them to the southern Oklahoma aulacogen is appropriate. Thus, we can trace the southern Oklahoma aulacogen as far northwest as the Cimarron arch.

3. The negative anomalies associated with the Las Vegas and Raton basins extend well beneath exposed Precambrian rocks. Thus, it is likely that these rocks are allochthonous.

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Canadian River and Canadian River Canyon at Sabinoso, New Mexico. View is S35°W upstream. Triassic rocks are exposed in banks to right of river. Jurassic and Cretaceous rocks underlie the west wall of the canyon in distance. Cottonwood and salt cedar trees are present on alluvium at left. Several outlying houses of Sabinoso are visible in middle distance. Camera station is in sec. 16, T17N, R24E. W. Lambert photograph No. 85L36. 8 April 1985, 1:55 p.m., MST.