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A GRAVITY STUDY OF THE JORNADA DEL MUERTO AND PALOMAS BASINS

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Abstract—The Jornada del Muerto, in south-central New Mexico, is an intermontane, synclinal basin. The Palomas Basin, a faulted, east-tilted graben, lies west of the Jornada, between the Caballo Mountains and the Black Range. There is an excellent correlation between gravity anomalies and Cenozoic tectonic features in both basins. The gravity high over the central Jornada del Muerto Basin is interpreted as being due, at least in part, to a mid-crustal, high-density, mafic intrusion; gravity lows of the southern and northern Jornada indicate the synclinal nature of the entire basin. The southern boundary of the Jornada del Muerto, located approximately 10 km northeast of the Doña Ana caldera, is modeled as a fault with throw approaching 4 km. This fault is probably the reactivated northern margin of the Laramide Rio Grande uplift.

INTRODUCTION

Gravity studies have proven very useful in efforts to elucidate structural relations in the Rio Grande rift (e.g. Cordell 1979, Decker et al. 1975, Keller et al. 1984). The Jornada del Muerto–Palomas Basin area (Fig. 1) is a structurally complex region of the Rio Grande rift, and the purpose of this paper is to use gravity and drilling information to analyze structural relations in this area.

Although this region has experienced a long and complex geologic history, Laramide and younger events are of greatest interest here because they are primarily responsible for the observed gravity anomalies. In general, the magnitude of gravity lows associated with basins in the area reflect the thickness of basin fill. This fill consists of: (1) Upper Cretaceous to Eocene fanglomerates, red beds, and sandstones of the Love Ranch and McRae Formations (locally as much as 1,000 m thick), which were deposited in the intermontane Love Ranch Basin of Seager & Mack (in press); (2) middle Tertiary volcanics derived from several possible sources (may locally approach thickness of 1,000 m); and (3) sediments associated with the formation of the Rio Grande rift (locally more than 1,600 m thick). Without the aid of drilling data, our ability to distinguish these units with gravity data is limited.

GRAVITY DATA

Field work was undertaken to fill in areas of sparse coverage in the gravity-data set of Keller & Cordell (1983). As a result, 90 terrain-corrected readings were added to this existing data base to produce the station density shown in Fig. 2. A complete Bouguer-anomaly map was constructed from the resulting data base (Fig. 3). A strong northwest to southeast regional gradient is apparent in the complete Bouguer map,

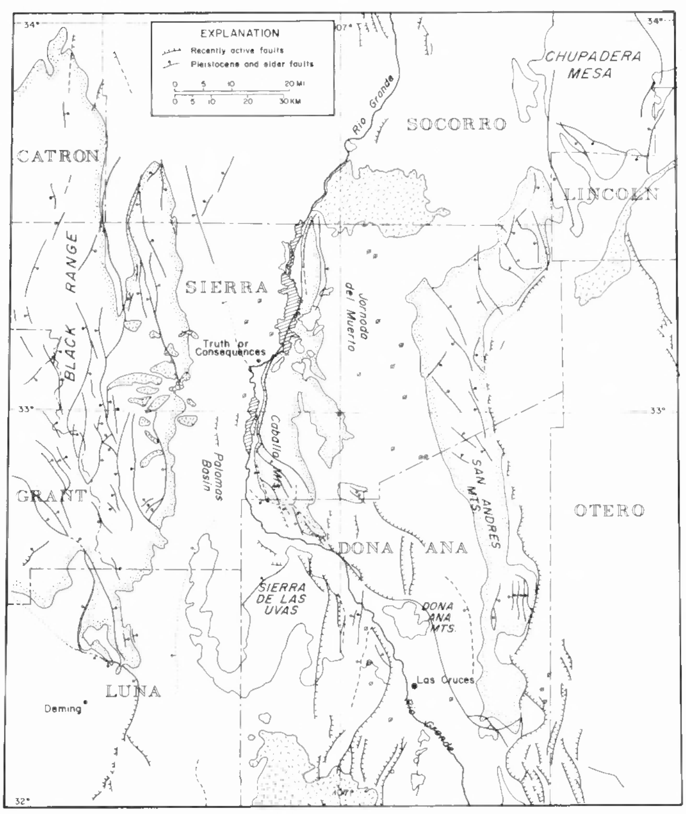

FIGURE 1—Index map showing major tectonic and physiographic features of the area (Callender et al. 1983). Pliocene and younger volcanics are shown by random dashed pattern. Wells are indicated by a circle with diagonal line.

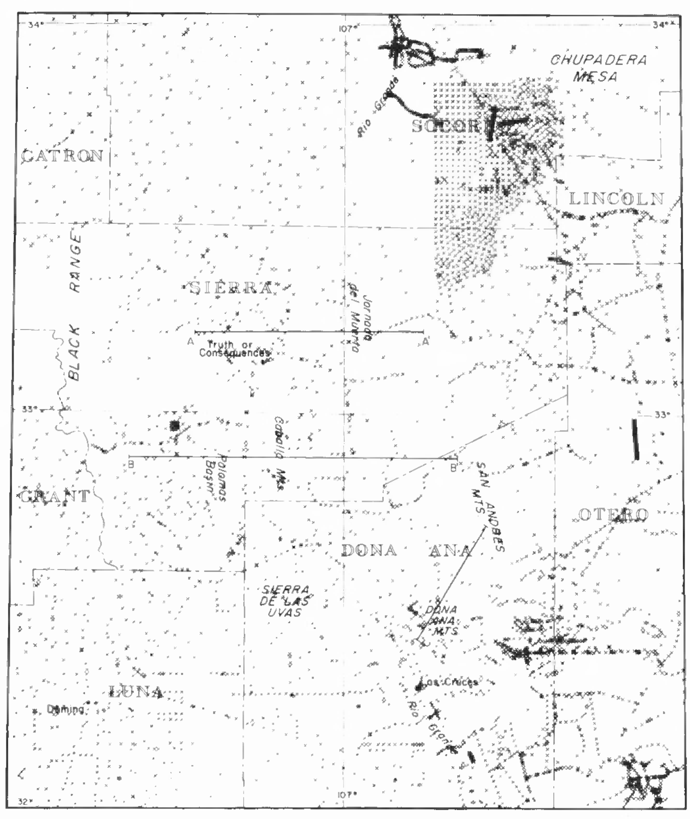

FIGURE 2—Map showing distribution of gravity stations in the study area. Profiles used in gravity modeling are also shown.

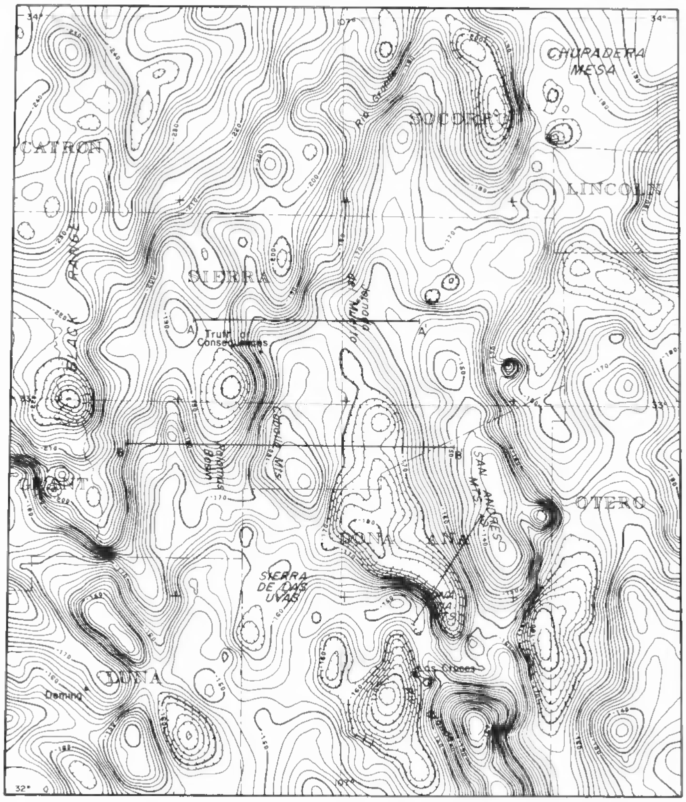

FIGURE 3—Complete Bouguer-anomaly gravity map of study area. Contour interval = 2 milligals; Datum = sea level; reduction density = 2.67 gm/cc. Profiles used in gravity modeling are also shown.

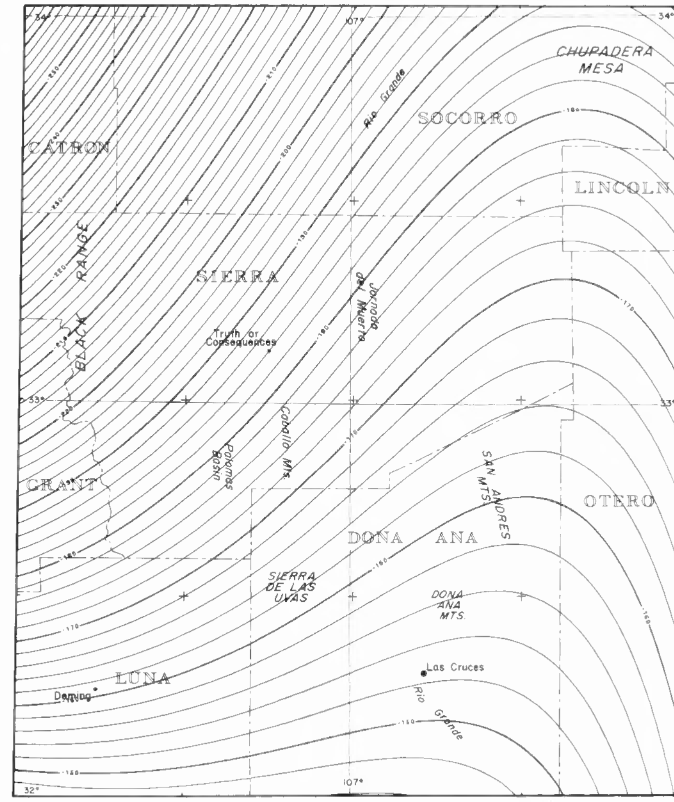

FIGURE 4—Third-order best-fit polynomial surface of the data shown in Fig. 2.

due largely to deep lithospheric structure (Decker et al. 1975, Daggett et al. in press). This regional trend was approximated by the third-order polynomial surface shown in Fig. 4. The residual-gravity map (Fig. 5) is the result of subtracting values on this surface from the corresponding Bouguer-anomaly values.

As an aid in interpreting the gravity data, three cross-sectional models were constructed across the area (Figs. 2, 3). These models (Figs. 6–8) are constrained by the available surface geology and well data. The following density units were used in the modeling (Fig. 6): basin fill (Qal)—2.35 gm/cc; syn- to post-orogenic Love Ranch and McRae Formations (Tlr, m)—2.4 gm/cc; Tertiary volcanics (Tv)—2.5 gm/cc; Mesozoic (pre-Laramide) and Paleozoic rocks (undifferentiated)—2.6 gm/cc; Tertiary and Upper Cretaceous intrusives (TKi)—2.7 gm/cc; Precambrian (p€) basement—2.7 gm/cc; and mafic intrusions—3.0 gm/cc.

In the area of interest (Fig. 1), Paleozoic strata generally thicken to the south and southwest (Greenwood et al. 1977), and range in thickness from 1,450 m in the Sun Oil Co., Victorio Land and Cattle Co., No. 1 well in the northwest portion of the basin to over 2,590 m in the southern portion of the basin as interpreted from seismic-reflection data (Keller et al. in this guidebook). Total thickness of Mesozoic strata (pre-Laramide) across the area does not exceed 701 m (Kottlowski et al. 1956). A map showing approximate thickness and distribution of basin fill (upper Quaternary alluvium, Santa Fe Group, Tertiary volcanics, and Love Ranch and McRae Formations) was derived from the third-order residual-gravity map and is presented in Fig. 9. This map was generated using the modeling technique employed by Keller et al. (1984) in their study of the San Luis Basin. In this technique, a simple Bouguer-slab approximation is used to model the residual-gravity value at each grid location. Thus, the negative residual anomalies are modeled as being due only to variations in fill thickness in an area of otherwise homogeneous basement. An average density difference of 0.2 gm/cc between the basin fill and the surrounding rocks was assumed.

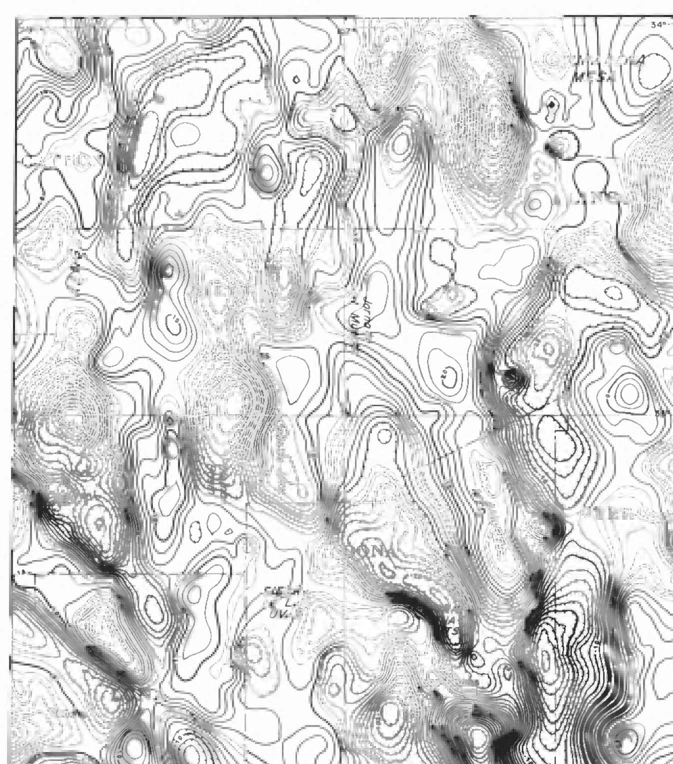

FIGURE 5—Residual-gravity-anomaly map of study area, constructed by subtracting values on the surface in Fig. 4 from corresponding Bouguer gravity values.

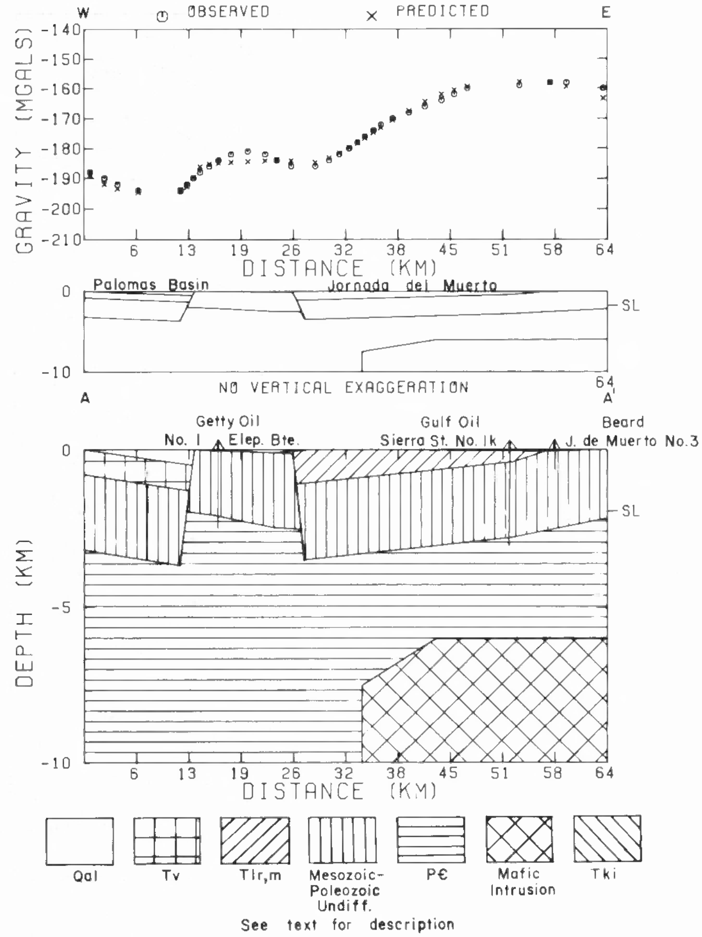

FIGURE 6—Gravity model for profile A–A′ (Figs. 2, 3). A two-dimensional technique with corrections for finite strike length was employed.

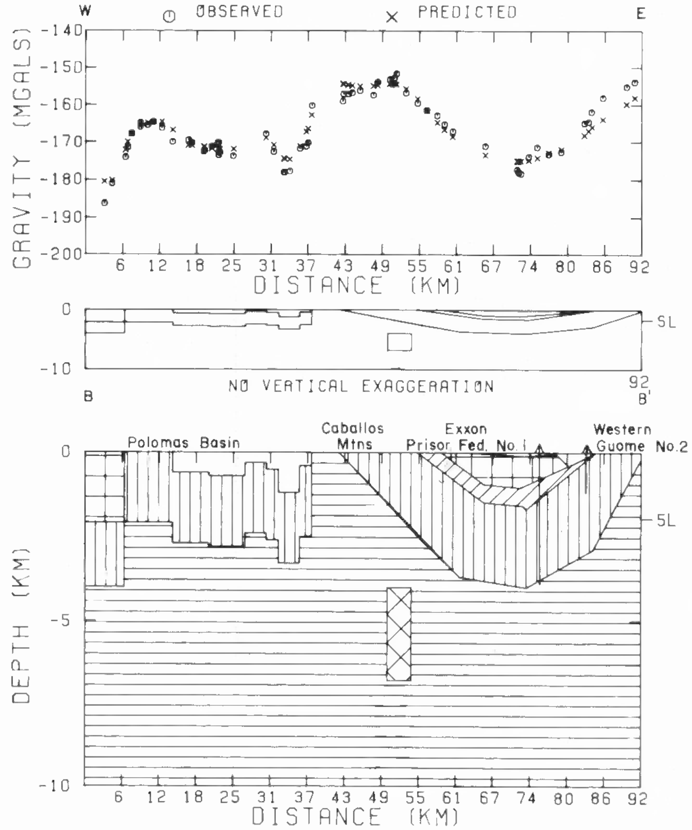

FIGURE 7—Gravity model for profile B–B′ (Figs. 2, 3). Patterns are identified in Fig. 6.

DISCUSSION

A number of interesting observations about gravity anomalies in the Jornada del Muerto–Palomas Basins can be made as a result of this study. First, there is an excellent correlation between gravity anomalies and late Cenozoic tectonic features. Laramide and earlier events seem to have left only very subtle gravity anomalies, primarily because the Paleozoic rocks of the Orogrande Basin are nearly as dense as the basement and change only gradually across the area. The Caballo and San Andres Mountains and the Palomas and southern Jornada del Muerto Basins are represented by gravity highs and lows, respectively (Figs. 3, 5), primarily reflecting the depth to basement rocks. The central portion of the Jornada del Muerto Basin (33°–33°30′N, 106°50′W) is associated with a gravity high (Figs. 3, 5) which separates the gravity lows of the southern and northern portions of the Jornada Basin. Well data from the central portion of the basin do not indicate the occurrence of basement rocks near the surface, suggesting that an intrabasement feature, not a fault block, is the source of this anomaly. We modeled this anomaly as a high-density, middle-crustal mafic intrusion (Figs. 6, 7), but recognize that other interpretations are feasible. An age for the source of this anomaly is difficult to diagnose because of the sparse well data in the area, but its north–south trend would suggest a late Cenozoic age.

This anomaly and similar anomalies associated with the Jarilla (32°10′, 106°15′) and northern Franklin Mountains (32°10′, 106°40′) seem to represent the major departure from a generally homogeneous basement which is a necessary assumption in the construction of Fig. 9. Thus, the basin-fill map of Fig. 9 is erroneous in the area of these gravity highs. However, the agreement between outcrop patterns, well data, and the basin-fill map in other areas suggests this map is generally valid elsewhere (with the exception of the effects of volcanics and intrusions in the Mogollon–Datil volcanic field).

The southern boundary of the Jornada and its relation to the Doña Ana caldera–Rio Grande uplift were modeled in Fig. 8. According to the model, a fault with throw approaching 4 km occurs approximately 10 km northeast of the caldera. We cannot determine the geometry of this fault/fault zone in detail, but it is high angle because of the extreme gravity gradient present. This fault would seem to mark the northern boundary of the Laramide Rio Grande uplift of Seager & Mack (in press). This fault appears to have formed a zone of weakness which was reactivated during formation of the Rio Grande rift, although the exact nature of the faulting was undoubtedly complex. The remainder of the cross section indicates the synclinal nature of the Jornada del Muerto Basin.

The gravity anomaly over the Palomas Basin (Figs. 3, 5, 7, 8) indicates a sharp gravity gradient on the east side of the basin and gentler gradients to the west. The western boundary fault of the Caballo Mountains, a late rift feature, uplifted Precambrian through Cenozoic rocks, resulting in their position adjacent to late Tertiary basin fill of the Palomas Basin. The density contrast of 0.35 gm/cc across this fault accounts for the steep gravity gradient. Gravity values gradually increase to the west in the basin in response to thinning of the basin fill (shallowing of the basin) westward. The dramatic decrease in gravity in Fig. 7 to the far west is due to the occurrence of the much less dense Tertiary volcanics and intrusions associated with the Black Range.

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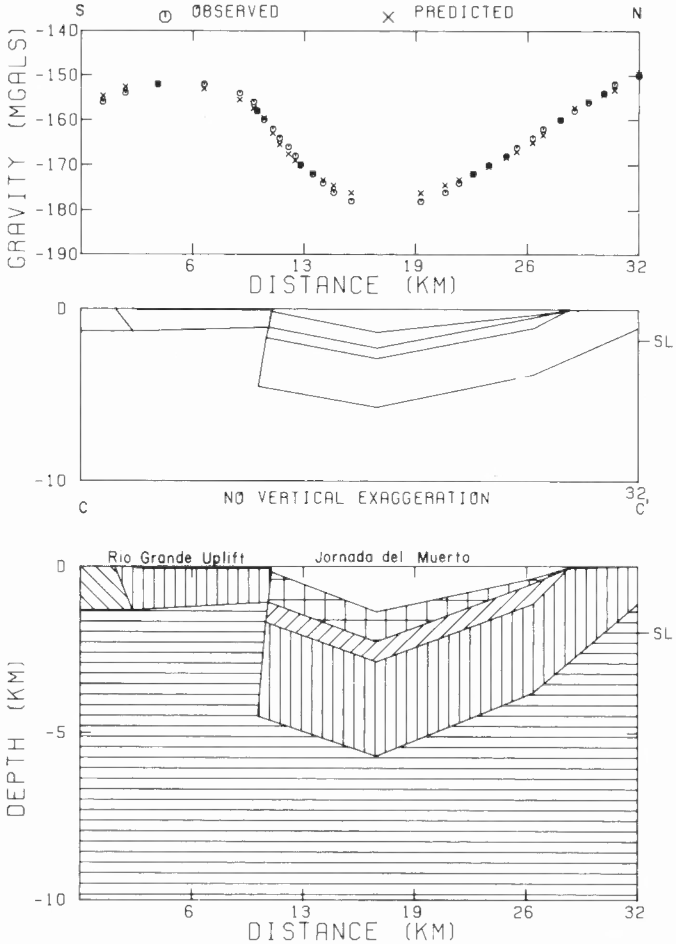

FIGURE 8—Gravity model for profile C–C′ (Figs. 2, 3). Patterns are identified in Fig. 6.

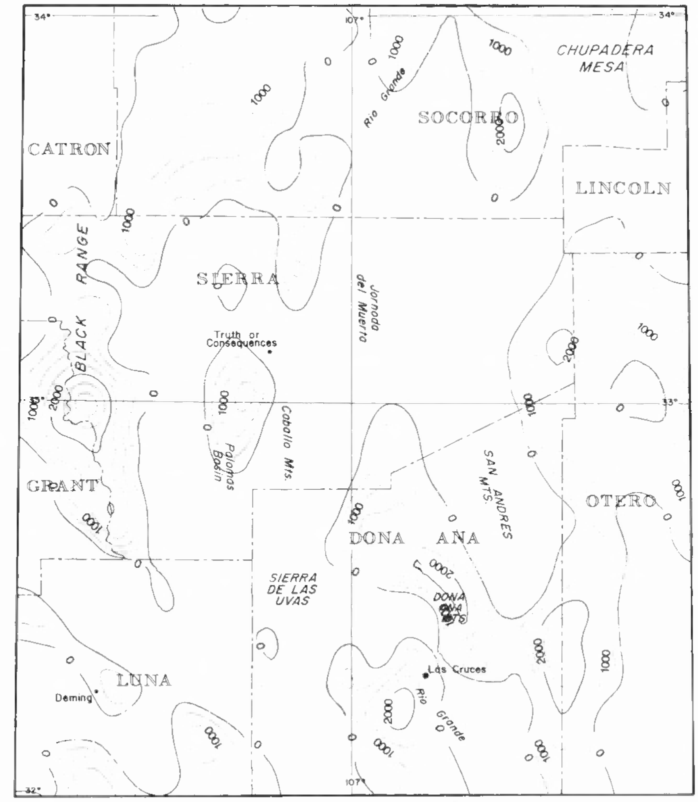

FIGURE 9—Calculated thicknesses of basin fill (Love Ranch–McRae Formations, Tertiary volcanics, Santa Fe Group, Quaternary alluvium). Calculations assumed a homogeneous basement (pre-Laramide rocks) and an average density contrast of 0.2 gm/cc between basement and basin fill. This assumption is clearly violated in the central Jornada del Muerto, Orogrande and northern Franklin Mountains, Black Range, and the region to the west. Contour interval = 500 m.

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