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1984, pp. 51-57. https://doi.org/10.56577/FFC-35.51

in:

Rio Grande Rift (Northern New Mexico), Baldridge, W. S.; Dickerson, P. W.; Riecker, R. E.; Zidek, J.; [eds.], New Mexico Geological Society 35th Annual Fall Field Conference Guidebook, 379 p. https://doi.org/10.56577/FFC-35

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A GEOPHYSICAL STUDY OF THE SAN LUIS BASIN

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INTRODUCTION

The San Luis Basin (Fig. 1) is an elongate intermontane valley located in south-central Colorado and north-central New Mexico. Stretching approximately 240 km in a north—south direction, it is bordered on the west by the San Juan and Tusas Mountains and on the east by the Sangre de Cristo Mountains. At its northern terminus near Poncha Pass, the valley is only 10-12 km wide, but it widens to approximately 75 km near Alamosa, Colorado. The valley floor, although appearing relatively flat, is built from the coalescence of alluvial fans which slope gently from the mountain flanks toward the center of the valley. Fifteen kilometers south of Alamosa, this sloping terrain is broken by the San Luis Hills, a series of flat-topped, low-lying volcanic hills extending along a north—south trend to the Colorado—New Mexico border. Geographically, the valley has been arbitrarily defined as terminating 15 mi south of the state line (Siebenthal, 1910). However, Upson (1939) noted that the valley is not a geological entity unto itself and instead merges southward into the Taos Plateau which is underlain by a Holocene volcanic field (Lipman and Mehnert, 1979). In this study, we have adopted the structural definition of the San Luis Basin (Kelley, 1956) and extended it to include the Taos Plateau with a southern termination at the Embudo constriction just southwest of Taos.

Since the early studies of Siebenthal (1910), Upson (1939), and Kelley (1956), the San Luis Basin has been recognized as being one of the major structural elements of the Rio Grande rift (Chapin, 1971). However, its subsurface configuration is poorly known, and it is thus a good target for geophysical studies. Early gravity studies (Gaca and Karig, 1965) were hampered by the lack of topographic maps. Cordell (1978) conducted a gravity study of the Taos Plateau region, and Davis (1979) conducted a gravity study of the Colorado portion of the San Luis Basin. These surveys became the major source of gravity data for this study and were merged into a consistent data base which was used to create Bouguer anomaly maps of the Rio Grande rift (Cordell et al., 1982) and New Mexico (Keller and Cordell, 1983). A Bouguer anomaly map of the San Luis Basin area is shown in Figure 2. Zietz and Kirby (1972) published a regional aeromagnetic map of Colorado, but the flight-line spacing was sparse in the San Luis Basin area. An aeromagnetic map of New Mexico has recently been completed (Cordell, 1983) and a portion of this map, which includes the southern San Luis Basin, is presented elsewhere in this volume. Seismic data of sufficient resolution to be of use in this study are very sparse. In fact, the reflection profiles of Davis and Stoughton (1979) are the only publicly available data. Although quite limited in areal extent, these data provide valuable constraints on the subsurface structure in the northernmost San Luis Basin.

Reviews of the geologic setting and history of the San Luis Basin area can be found in Baltz (1965, 1978), Tweto (1979), Lipman and Mehnert (1979), and Woodward and Ingersoll (1979). The brief discussion which follows is based on these studies and documents the main aspect of the geologic history impacting geophysical interpretations, which is the fact that little or no pre-Eocene Phanerozoic rock is present beneath the basin because the region has been high-standing throughout most of the Phanerozoic. During the early Paleozoic, the area was located on the Transcontinental arch. The Uncomphagre—San Luis highland extended through the area in the Pennsylvanian, but its eastern margin may have been located in the eastern portion of the area presently occupied by the San Luis Basin. The entire region was uplifted again during the Laramide orogeny as part of the Sangre de Cristo—Brazos uplift and virtually all pre-existing sediments were eroded away at that time. Some Eocene alluvium was deposited at least locally (Tweto, 1979), and then rocks of the San Juan volcanic field covered the area in the Oligocene (Steven, 1975). Drilling data and outcrops in the Taos Plateau area, San Luis Hills, and Sangre de Cristo Mountains confirm that these volcanic rocks still underlie the basin. The formation of the Rio Grande rift caused block faulting which has preserved these volcanic rocks in the resulting grabens. Thus, for the purpose of geophysical interpretations, the basin can be considered to consist of graben fill overlying Oligocene volcanic rocks which lie on the Precambrian basement.

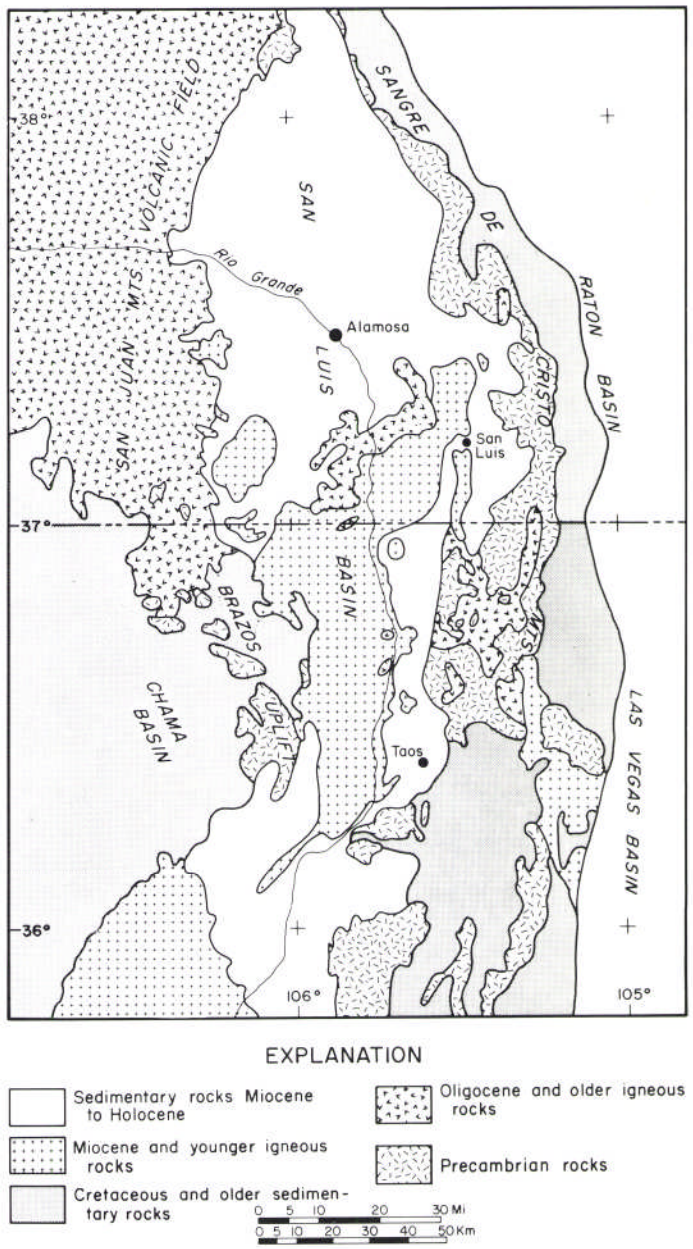

FIGURE 1. Generalized geologic map of the San Luis Basin area.

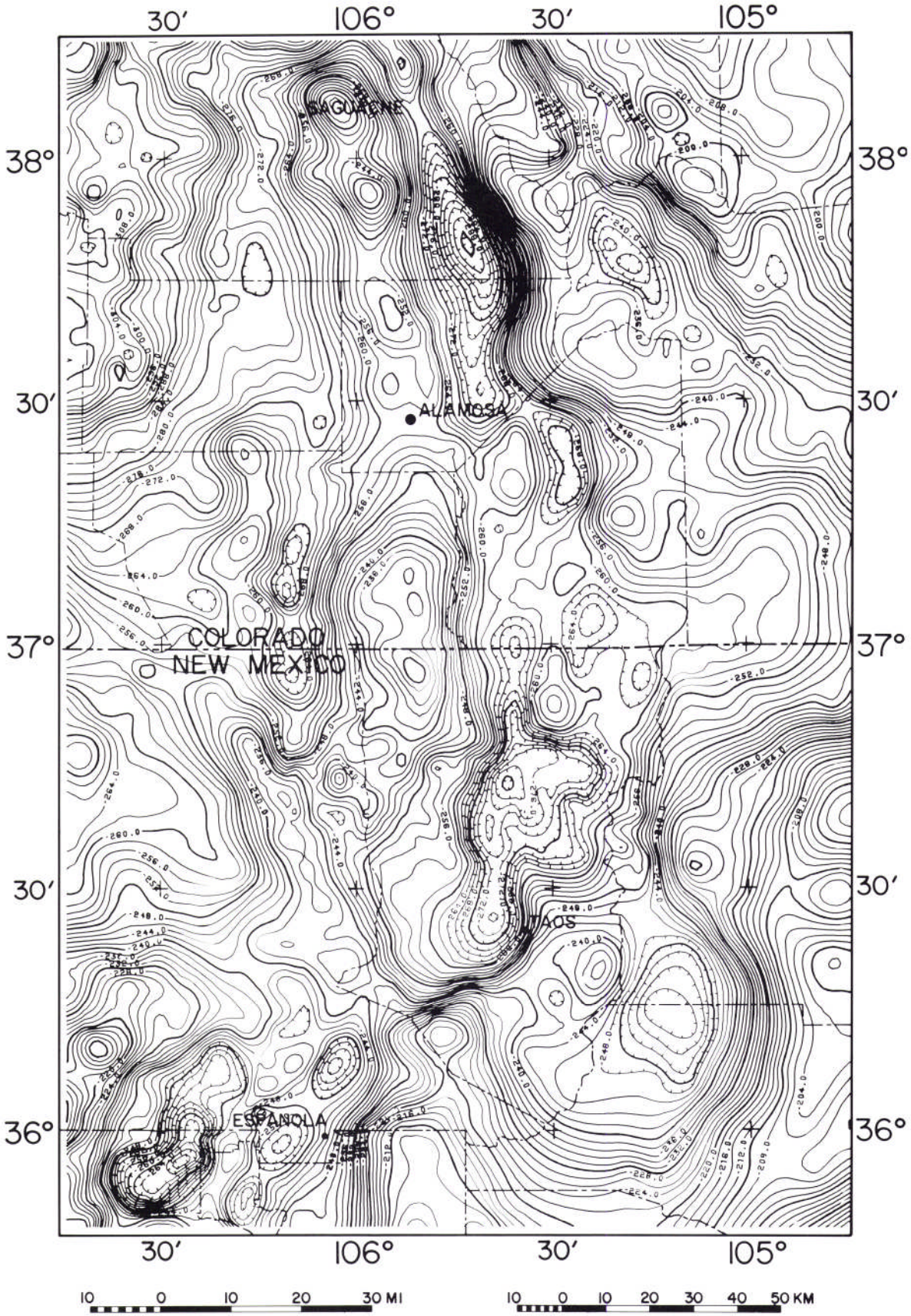

FIGURE 2. Bouguer anomaly gravity map of the San Luis Basin area. Contour interval = 2 mgal. Datum = sea level. Bouguer reduction density = 2.67 gm/cc.

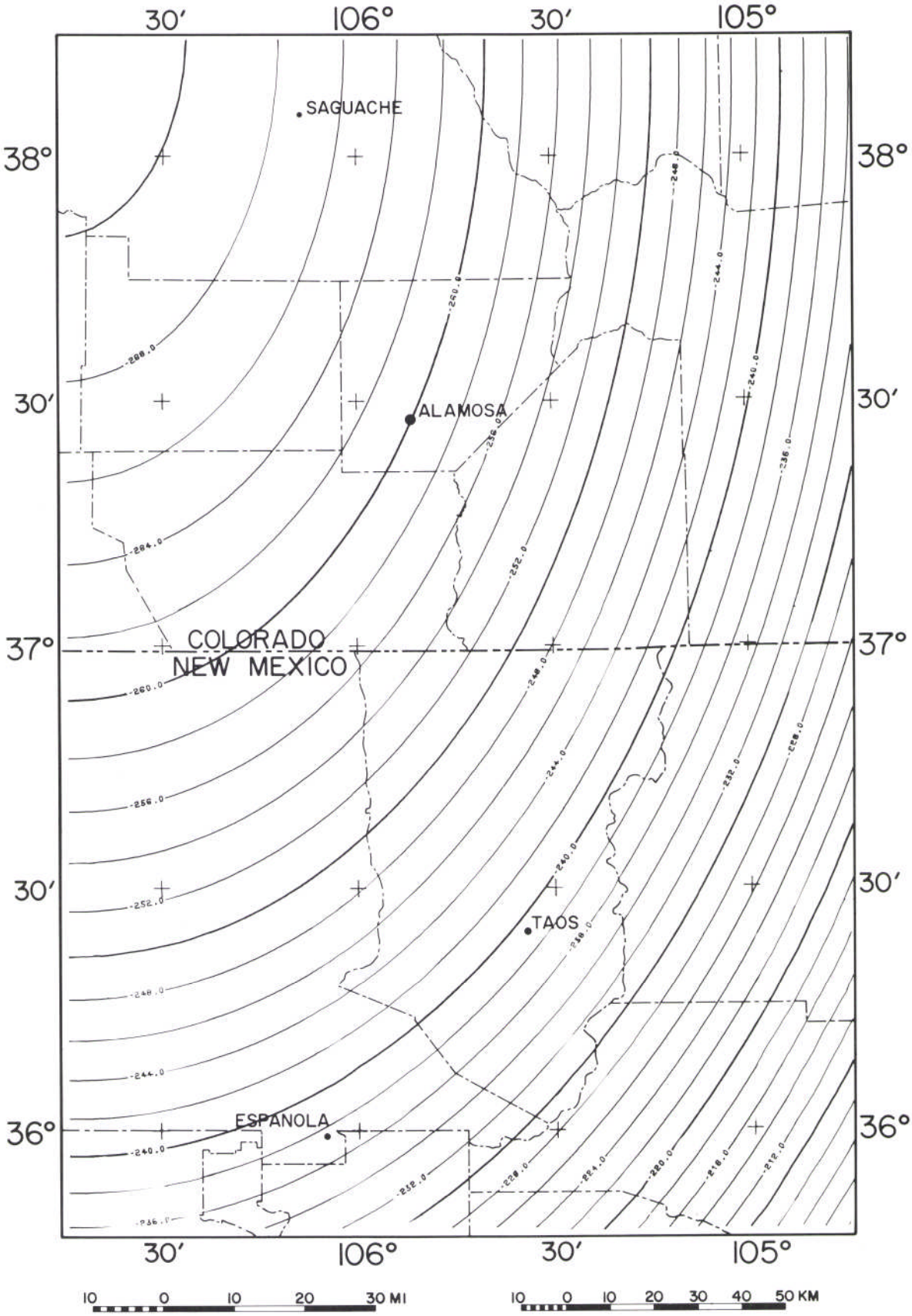

FIGURE 3. Regional gravity trend in the San Luis Basin area as modeled using a second-order polynomial surface. Contour interval = 2 mgal.

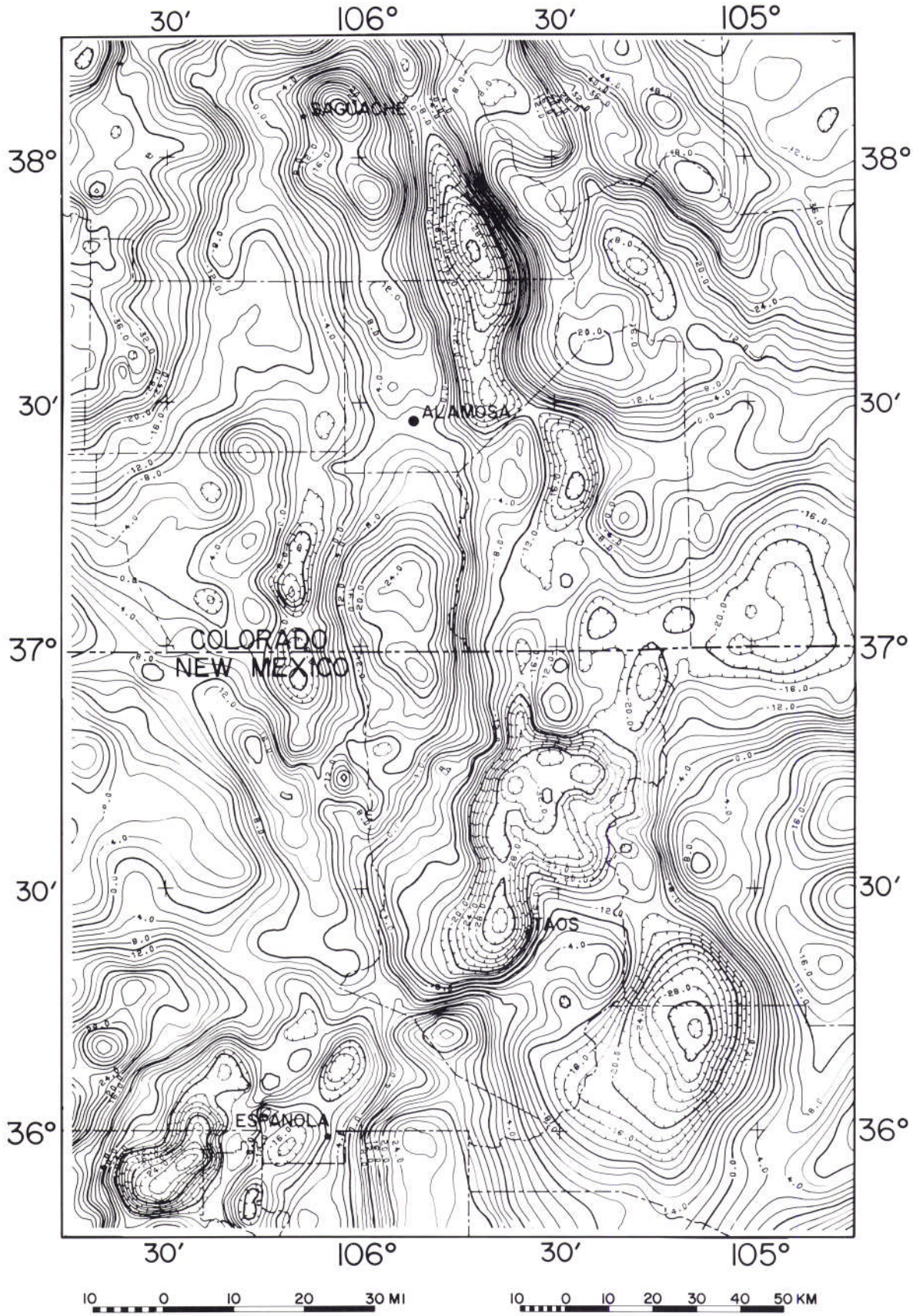

FIGURE 4. Residual gravity anomalies in the San Luis Basin area. These values were obtained by subtracting values on the surface shown in Figure 3 from the Bouguer anomaly values displayed in Figure 2. Contour interval = 2 mgal.

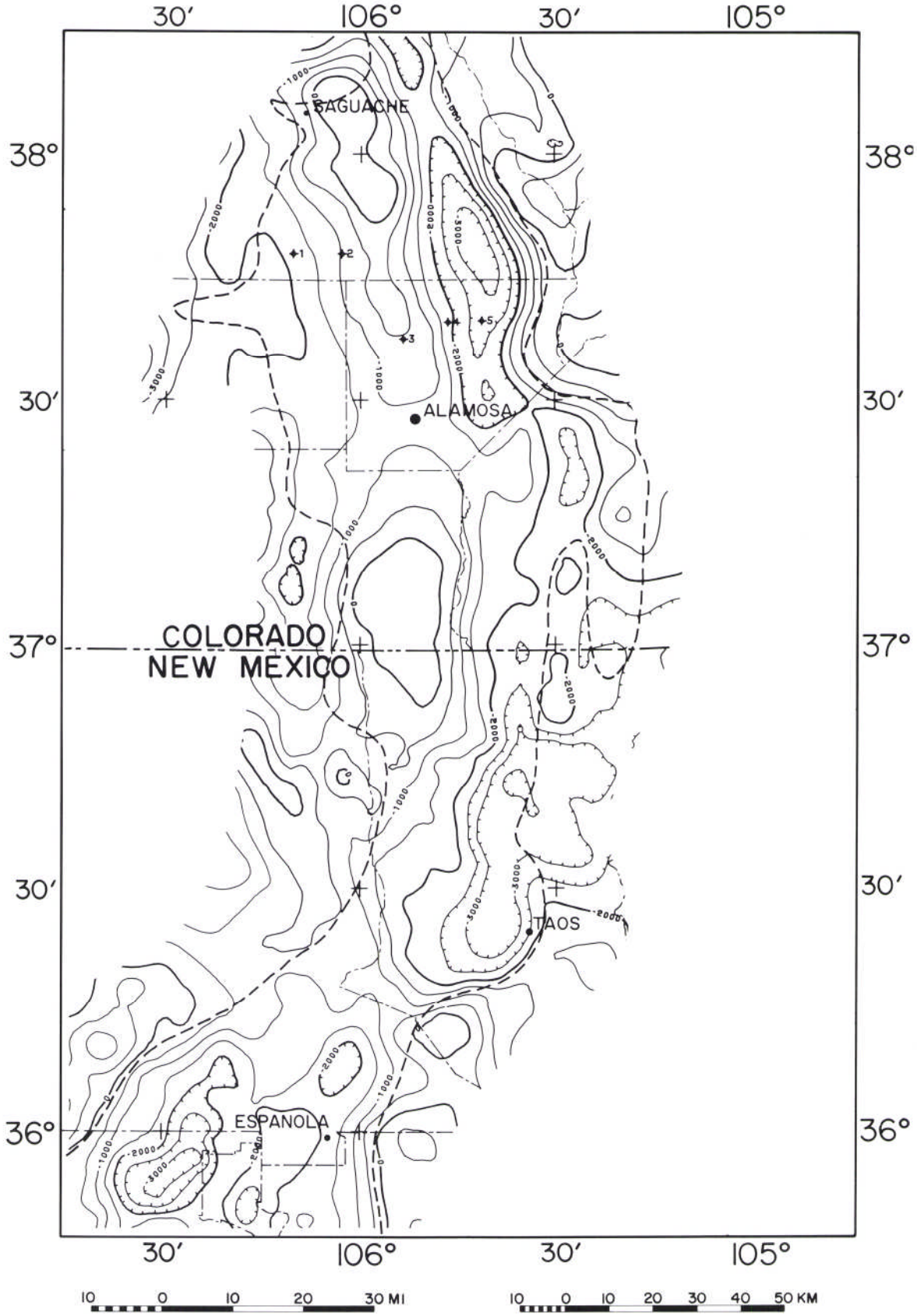

FIGURE 5. Contour map of estimated depth (meters) to the base of the bolson fill. The calculations assumed a density contrast of 0.35 gm/cc between the fill and adjacent rocks. Contour interval = 1,000 m. Wells used for calibration are shown as circles with crosses. Approximate boundary of the basin in dashed line.

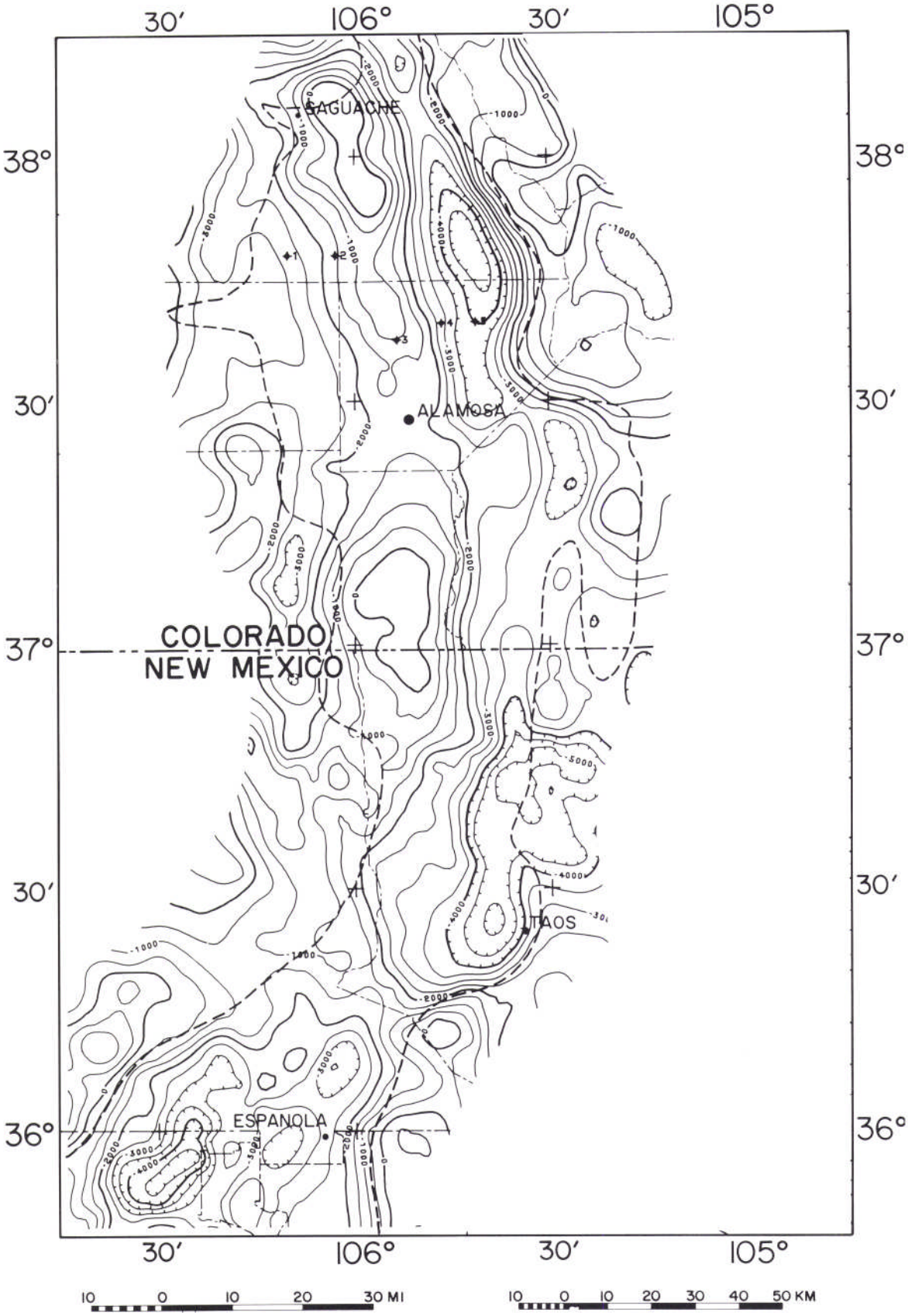

FIGURE 6. Contour map of estimated depth (meters) to the Precambrian basement. The calculations assumed a density contrast of 0.25 gm/cc between the basement and younger rocks. Contour interval = 1,000 m. Wells used for calibration are shown as circles with crosses. Approximate boundary of the basin in dashed line.

GEOPHYSICAL DATA AND ANALYSIS

With the exception of a small addition of data in the Sangre de Cristo Mountains, the data base of gravity readings used in this study is the same as shown on the maps of Cordell et al. (1982) and Keller and Cordell (1983). The reduction parameters and procedures are given in Cordell et al. (1982). A major consideration is that all these data have been terrain-corrected for topography in a zone extending from 0.875 km to 166.7 km from each station. These corrections were calculated using the technique of Plouff (1977). However, the resulting complete Bouguer anomaly values cannot be interpreted quantitatively without further processing because a large regional variation in the gravity field is present and distorts the local anomalies due to features such as basin fill. This regional variation was modeled by fitting a second-order polynomial surface to the data in the area encompassing all of southern Colorado and northern New Mexico using the technique of Lance (1982). Contour values of this surface in the San Luis Basin area are shown in Figure 3. In this area, the regional gravity field can essentially be represented by a linear increase in gravity values from west to east. That this is an appropriate choice of regionals can be verified by looking at individual profiles (e.g., Davis, 1979). This removal of the regional can be considered as a high-pass filter with the residual gravity values (i.e., the differences between the grid of observed values and the corresponding second-order surface values) representing the high-frequency component being passed. A map of these residual gravity values is shown as Figure 4. It is geologically reasonable (but not necessarily valid) to assume that density variations within the basement are small. Thus, the gravity anomalies in San Luis Basin area (Fig. 4) would be at least mostly due to variations in the thickness of the basin fill and underlying volcanic rocks. A linear gravity high delineates a prominent N–S trending horst running up the center of the basin. The San Luis Hills and outcrops of Oligocene volcanic rocks in the Taos Plateau (Lipman and Mehnert, 1979) represent exposures of this horst whose presence is also indicated by drilling data (Tweto, 1979) and seismic-reflection data (Davis and Stoughton, 1979). The deepest portions of the basin generally lie along the western margin of the Sangre de Cristo Mountains (Cordell, 1978; Davis, 1979), and the smaller graben west of the horst dies out to the south as the Taos Plateau is encountered.

In an attempt to quantify the estimates of basin fill, we have applied the computer-modeling techniques of Wen (1983) to the residual anomalies. This technique assumes that the regional has been adequately removed and that a single density contrast between basin fill and basement is a good approximation to reality. The results are shown as contour maps of the thickness of basin fill in Figures 5 and 6.

Five deep oil tests in the San Luis Basin were used to calibrate the choice of density contrasts for the fill-thickness determinations. These wells are located in Figures 5 and 6. A bulk-density log was available for the Amoco Mapco 1-32 state well. This log showed that the density of the fill averaged 1.9 gm/cc for the interval extending from the surface to 570 m, 2.1 gm/cc from 570 m to 1,325 m, and 2.3 gm/cc from 1,325 m to 2,630 m. Oligocene volcanic rocks were encountered at 2,630 m and had an average density of 2.6 gm/cc. The biggest unknowns in the modeling were the density of the basement rocks and the extent of Eocene sedimentary rocks. However, a density contrast of 0.35 gm/cc produced a good fit between calculated fill-thickness values and drilling data. Thus, the map shown as Figure 5 can be considered to display the general distribution of post-Oligocene basin fill. A density contrast of 0.25 gm/cc produced a good fit between the calculated-thickness values and the depths to Precambrian basement from drilling data. Thus, Figure 6 cn be interpreted to indicate the approximate depth to Precambrian basement.

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The southbound train at Española in 1941. The locomotive is a K-28 class, outside frame Mikado, built in 1923 and used on the "Chili Line" after 1933 (photo by Bob Richardson).