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LAS CRUCES COUNTRY: A GEOPHYSICAL AND REMOTE SENSING PERSPECTIVE

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Abstract—The Las Cruces region is in a structurally complex region where the Rio Grande rift intersects the Basin and Range province and several older structural trends. Thus, the integration of a variety of data is required to unravel the tectonic history of this region. Here we present a filtered gravity map and Landsat Thematic Mapper mosaic of the region and make a few observations about their utility and implications.

INTRODUCTION

The Las Cruces region (Fig. 1) is in the center of the southern Rio Grande rift in a complicated confluence of tectonic features. In addition to the rift, these features include the several Laramide uplifts and basins (Seager and Mack, 1986; Seager et al., 1997), late Paleozoic features that include the Orogrande and Pedregosa Basins (e.g., Ross and Ross, 1986), and Precambrian structures that represent the formation and break-up of the North American craton (Laurentia). The tectonic framework of this region has proven difficult to unravel because the surface structure is complex, exposures of pre-Cenozoic rocks are widely scattered, subsurface data from deep drill holes are scarce, and detailed geophysical data are only available in a few areas. Thus, it is important to integrate as wide of a variety of geological and geophysical data as possible in efforts to address the tectonic evolution of this region. The purpose of this paper is to summarize briefly geophysical studies in this region and present a synoptic view of the region from space. In addition to regional geologic maps, the readily available data sets that cover the entire area are Landsat Thematic Mapper (TM), gravity, and aeromagnetics. The Pan American Center for Earth and Environmental Studies (PACES) was established at the University of Texas at El Paso with one part of its mission being to disseminate data to the scientific community. Thus, another purpose of this paper is to present some of these data and illustrate their utility.

DEEP CRUSTAL STRUCTURE

Major tectonic events such as plate collisions and the formation of rifts usually leave a major imprint on crustal structure. Rifting involves crustal thinning and the amount of thinning is particularly important in efforts to determine the amount of extension that has occurred (e.g., Morgan et al., 1986). The southern Rio Grande rift has been the target of a number of seismic refraction studies, which when integrated with gravity data, provide a good general picture of crustal structure (Toppozada and Sanford, 1976; Olsen et al., 1979; Cook et al., 1979; Jaksha, 1982; Daggett et al., 1986; Sinno et al., 1986; Roberts et al., 1991, 1994; Schneider and Keller, 1994). However, none of these refraction profiles have the close station spacing (<1 km) and shot spacing (<50 km) that would reveal interesting structural details. Nevertheless, these seismic results and gravity data have been combined to provide a regional view of crustal structure by Keller et al. (1990) and Adams and Keller (1994) which shows that rifting has thinned the crust by at least 5 km. On a more regional scale, seismic and gravity data show that from Albuquerque southward, the area of crustal thinning widens (Cordell, 1982; Keller et al., 1990) as does the physiographic expression of the rift. In addition, the elevation of the rift valley floor and the thickness of the rifted crust decrease southward. Cordell's (1982) analysis of gravity anomalies also indicates that the amount of extension increases southward from central Colorado to the Las Cruces region. Keller et al. (1991) compared the Kenya and Rio Grande rifts showing that they are similar in scale. In Kenya, an analogous situation exists because, as one proceeds northward from the apex of the Kenya topographic dome to the Lake Turkana area, the physiographic expression of the rift and the region of crustal thinning widen. In addition, the crust thins, the elevation of the rift valley floor decreases, and the amount of extension increases northward. Thus in the Kenya rift, the thinnest crust, lowest elevations, and greatest extension occur in the Lake Turkana area, while the same is true for the Las Cruces area of the Rio Grande rift.

STRUCTURE OF THE UPPER CRUST

We must depend on seismic reflection data, drill holes, and other geophysical data to obtain information on the subsurface geometry of mapped geologic features. In the Las Cruces region, petroleum exploration has led to the collection of seismic reflection data along many profiles, but the vast majority of these data remain confidential. Those data that have been released and published (Keller et al., 1986; Figuers, 1987; Adams and Keller, 1994) reveal the subsurface structure of the Rio Grande uplift northeast of Las Cruces, the Palomas Basin, and the Franklin Mountains respectively.

The structure of Cenozoic basins in the region has been the topic

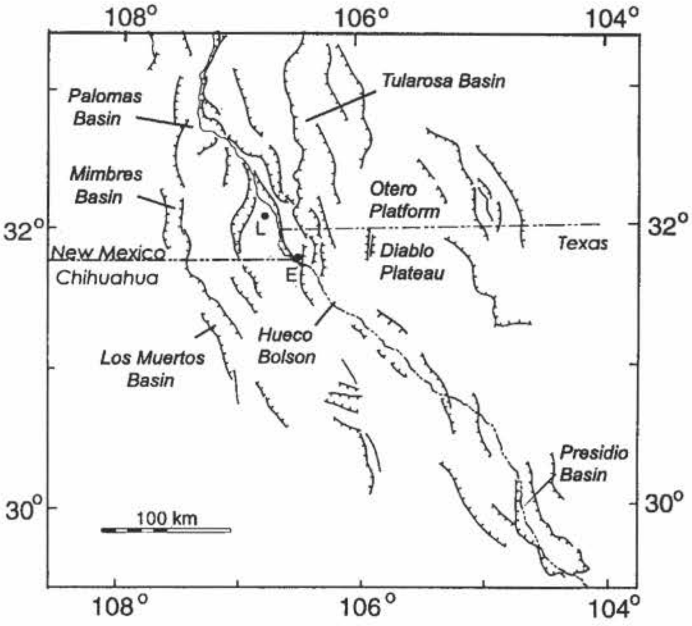

FIGURE 1. Tectonic index map of seismic studies in the Rocky Mountain region.

FIGURE 2. Landsat Thematic Mapper mosaic. Color version is on inside cover of this guidebook.

of a number of geophysical studies. They include regional gravity analyses by Ramberg et al. (1978), Decker and Smithson (1975), and Daggett et al. (1986), and studies of individual features such as the Palomas Basin (Gilmer et al., 1986; Adams and Keller, 1994), the Hueco Bolson (Mattick, 1967; Collins and Raney, 1994), and the Mesilla Bolson.

Mid-Tertiary magmatism affected the Las Cruces region significantly (Seager, 1981, Seager et al., 1984) and is of a scale that the structure of the crust was certainly altered. The clearest example of crustal-scale alteration is the Datil-Mogollon volcanic field, which was the target of a fairly detailed seismic and gravity study (Schneider and Keller, 1994). Here, an upper crustal body 5–10 km thick with low seismic velocity and density was detected and presumably represents the batholith that was the source of the volcanics (e.g., Elston, 1976). However, compared to this batholith, individual intrusions of this age in southern New Mexico are generally too small to be delineated with the existing geophysical data sets.

Laramide structures in the Las Cruces area are prominent on some industry seismic reflection data, and the profile crossing the Rio Grande uplift images it well (Keller et al., 1986). Sediments in post-Laramide (Love Ranch) basins are low density so they produce gravity lows. However, drill hole control is needed to distinguish these basins from younger ones (Gilmer et al., 1986).

The Paleozoic Orogrande and Pedregosa Basins (e.g., Ross and Ross, 1986) are relatively broad features and the dominantly carbonate rocks that fill them have seismic velocities and densities that are almost as high as those of the crystalline Precambrian basement. Thus, these rocks are hard to detect with regional geophysical data.

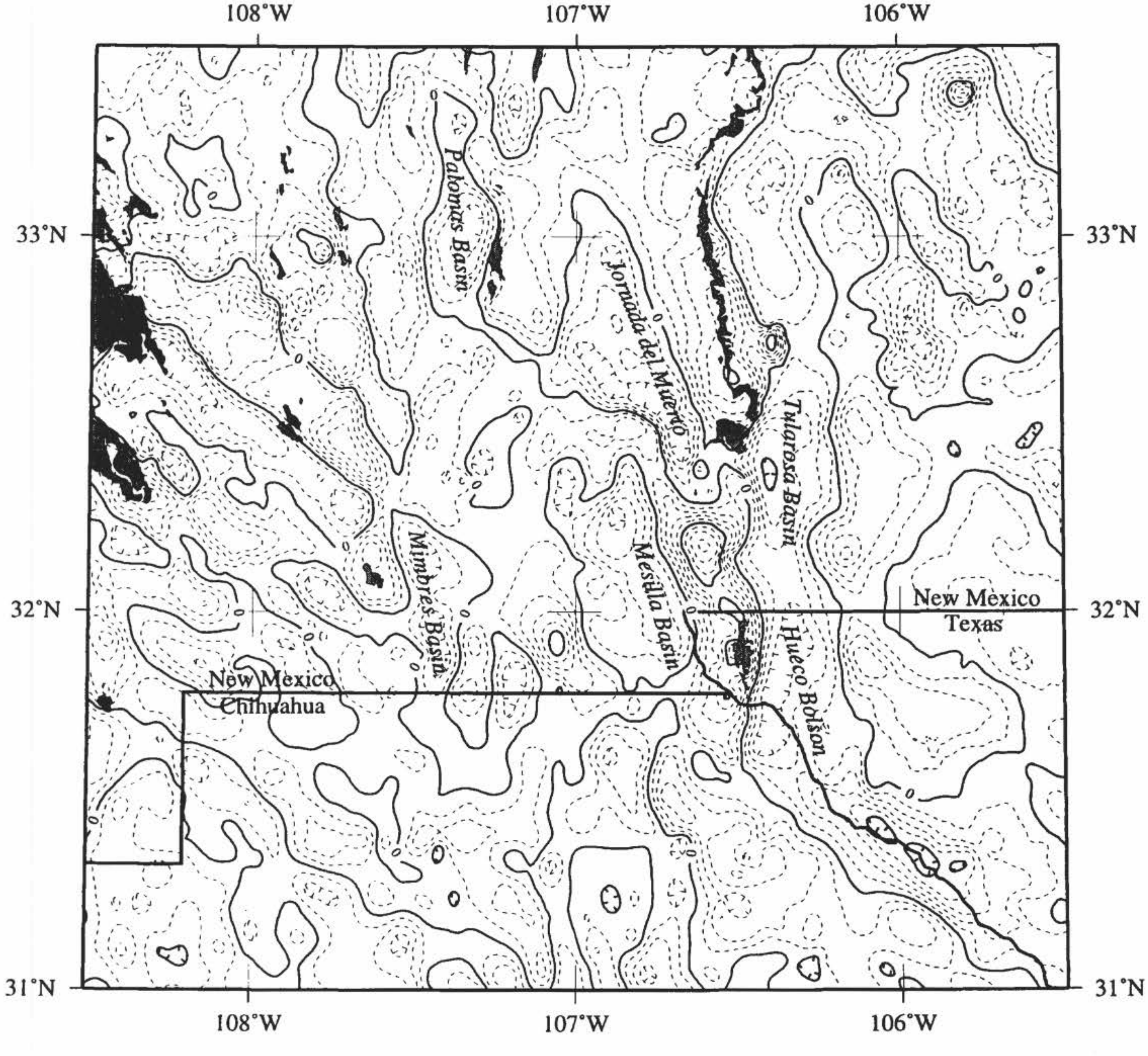

FIGURE 3. Filtered gravity map of the Las Cruces region. To construct this map, Bouguer anomaly values were filtered to pass wavelengths between 5 and 125 km. Daggett et al. (1986) demonstrated that this filter would remove the effects of deep crustal structure and result in a map that emphasizes upper crustal structures. Dark areas are exposures of Precambrian rocks.

LANDSAT MOSAIC

Thematic Mapper (TM) is an instrument that was mounted on the Landsat 4 and 5 satellites. Landsat 4 was launched in 1982 and Landsat 5 is due to be replaced by Landsat 7 during the summer of 1998. The TM instrument collects data, in six wavelength bands, on the intensity of electromagnetic energy reflected from the Earth's surface. Three of these bands are in the range of visible light and three are in the reflected infrared range. The spatial resolution of the data in these bands is about 30 m, which means that each pixel in the image represents the average reflectance over an area this size. In addition, data in a seventh (long wavelength) band focused on thermal radiated energy is collected at a lower spatial resolution (120 m). Each TM scene covers an area about 180 km x 180 km. By choosing any three bands of data and entering them in the red, green, and blue guns in a computer display, one can create a wide variety of false color images.

In this study, we created a mosaic of six TM scenes covering the Las Cruces region. Standard processing procedures were employed including application of a histogram match algorithm. We then determined that bands 7, 4, and 2 produced the most useful false color image, which is shown in black-and-white on Figure 2 and in color on the inside cover of the guidebook. This image clearly shows the main geologic features in the region. Close-up views of specific areas allow rock types to be identified and structures to be mapped. For example, Maciejewski and Miller (this guidebook) discuss how these TM data helped identify rock types in the San Andres Mountains and the portions of the pediment for which they served as the source terrane. Also, one can count the cinder cones in the Potrillo volcanic field by their distinctive red tops. Our main purpose here is to present this image as a synoptic view of the Las Cruces region.

GRAVITY MAP

Gravity data are a ready source of information to augment the TM data by providing a generalized view of subsurface structure. In this study, we employed a gravity database that our group maintains and updates regularly. We reduced the observed gravity data to Bouguer anomaly values using a sea level datum and a reduction density of 2.67 gm/cm^3. Following the studies of Daggett et al. (1986) and Keller et al. (1990), we filtered the Bouguer anomaly values so that only wavelengths between 5 and 125 km were passed (Fig. 3) in order to accentuate geologic structures in the upper crust.

DISCUSSION

By looking at Figures 2 and 3 together, several observations are clear. First, the subsurface structure of the region is far more complex than the physiography would suggest. Based on drilling and gravity modeling results (e.g., Ramberg et al., 1978; Daggett et al., 1986; Gilmer et al., 1986; Adams and Keller, 1994), we can conclude that the highly negative regions on the gravity map generally delineate the areas of maximum sedimentary fill in the basinal areas. An example of the structural complexity is the region from the Organ-Franklin Mountains chain to the Florida Mountains, which based on surface information would be expected to be a broad gravity low with a high region in the area of the East Portrillo Mountains. However, the gravity field is very complex revealing a series of buried horsts and grabens in the region. Also, the Orgrande area is revealed to be at the southern end of a large intrabasinal horst block that extends northward along the entire length of the Tularosa basin. The dominance of the northwest structural grain of the region west of Deming is also obvious and is more pronounced in the gravity anomalies than in the surface structure. From a water resources point of view, these maps predict where deep aquifers are most likely to exist.

ACKNOWLEDGMENTS

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South-facing scarp of the Caballo Mountains north of Longbottom Canyon. Stratigraphy includes the Cambro–Ordovician Bliss Formation (well-bedded, dark rocks near base of cliff), the Lower Ordovician El Paso Formation (middle cliff, light-colored slope, and light-colored part of upper cliff), and Upper Ordovician Montoya Formation (dark part of upper cliff). Light-colored rocks at bottom of photograph are highly deformed Paleozoic rocks in a horse between south-dipping reverse faults of probable Laramide (latest Cretaceous–Eocene) age. Photograph by Greg Mack.