LONG-TERM DEFORMATION IN THE SOUTHERN RÍO GRANDE RIFT AS INFERRED FROM TOPOGRAPHY AND UPLIFTED TERRACES

LINDA KAY ARMOUR

Department of Geological Sciences

APPROVED:

Richard P. Langford, Ph.D., Chair

Thomas E. Gill, Ph.D.

Richard S. Jarvis, Ph.D.

Terry L. Pavlis, Ph.D.

Robert C. Trentham, D.G.S.

Benjamin C. Flores, Ph.D.
Dean of the Graduate School

Dedication

to Glen and Alma Armour who made this possible
and
Marcia and Glenda who tolerated years of Mom's night classes

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LINDA KAY ARMOUR, BA, BS, MS

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ABSTRACT

This study examines Basin and Range topography relating tectonic processes to topographic features. The observation that the terraces along either side of the Franklin Mountains were deformed and uplifted is a reflection of tectonic uplift. The uplift represents long-term deformation of the range. This led to the question of what shapes the deformation and does it represent differential subsidence into the Rio Grande Rift or true uplift. A more regional study of the Sacramento, San Andres, and Guadalupe Mountains follows. Two papers form this dissertation.

The Río Grande Rift and the Franklin Mountains, in particular, are the subject of the second chapter. The indication for tectonic uplift is the terraces along the flanks of the Franklin Mountains mimicking the curve along the crest of the range.

In light of the results from the Franklin Mountains, Chapter three examines the Sacramento, San Andres, and Guadalupe Mountains. Location data were converted to UTM Zone 13 measurements then long-wavelength elevation changes were modeled by use of transects drawn from digital elevation models (DEM) at 15 minute intervals between the Pecos River of eastern New Mexico across to Arizona on the west. A 2^{nd}order polynomial was fit across the transects then a map was constructed based on the polynomials. The three modeled ranges are among those that show uplift above the smoothed surface. Furthermore, the ranges all exhibit arcuate crests implying a similar origin. A gravity map between 31° N, -104° W and 35° N, -110° W was multiplied by the inverse of elevation to emphasize the correlation between elevation and subsidence into the rift basins.

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CHAPTER 1: INTRODUCTION

This study examines the Basin and Range province topography and relates it to local tectonism. The Franklin Mountains are flanked by terraces that have been deformed. Their uplift represents long-term deformation of the range. This led to the question of what was the shape of the deformation, and whether it represented differential subsidence or true uplift. The study expanded to a more regional study that included the Sacramento and Guadalupe Mountains and then to the Basin and Range as a whole. Two papers, comprising Chapters 2 and 3 resulted from this research.

The Chapter 2 investigates the Río Grande Rift and the Franklin Mountains. Terraces were mapped using a high resolution GPS to determine the elevations of the highest terraces underlain by basin-floor sediment. Uplift of the Franklin Mountains was demonstrated by a topographic profile of terraces that on the east and west flanks mimicking the crest of the range is indication of tectonic uplift.

Chapter 3 compares the Guadalupe, San Andres, and Sacramento Mountains in light of the results from the Franklin Mountains. First, a gravity map that combines gravity with topography was created. Digital elevation models (DEM) were profiled at 15 minute intervals between latitude 31 and 35, between longitudes 104 and 110 west. A second degree polynomial was fit to the transcripts and a smoothed surface was constructed. This was related to the uplift history of the ranges and to the evidence of tectonic uplift versus differential subsidence was discussed.

CHAPTER 2: LONG-TERM DEFORMATION IN THE SOUTHERN RÍO GRANDE RIFT AS INFERRED FROM TOPOGRAPHY AND UPLIFTED TERRACES

ABSTRACT: The long-term deformation of the Franklin Mountains in the Río Grande Rift was estimated by measuring the elevation of Late Pliocene terraces that line the footwalls of the range-front faults. In most extensional terrains, alluvial fans and bajadas cover faults and terraces thus making documentation of long term uplift difficult. However, rapid aggradation of the basin floors by extensive playa lakes and floodplain deposits of the Río Grande river buried the irregular mountain front fans creating the low-gradient surface. Subsequent faulting deformed and uplifted the low-gradient surface, revealing the long-term deformation of the mountains.

The uplifted terraces are exposed along both sides of the Franklin Mountains and along the east side of the Sierra Robledo in south central New Mexico. In the Franklin Mountains, the terraces lie 130 m above a younger surface, indicating that this is the minimum amount of uplift. The profile of the anticline parallels the profile of the range crest of the mountains. Three important conclusions can be drawn from uplift of the terraces. First, the observation that the terraces parallel the range crest implies that the topography of the mountains is tectonic in origin and that there was a low relief surface prior to deformation. Second, the east side terraces are higher than the west side terraces, showing rotation of the mountains during deformation, and providing an estimate of the percentage of deformation recorded by the terraces at about five percent of the total rotation. Third, the open arch correlates points to differential slip on the fault plane as a factor in the uplift.

Two models for causing the differential slip associated with apparent uplift are 1) differential subsidence that results in the denudation of the horst blocks that are subsiding less rapidly and 2) true uplift, related to flexural deformation along with the fault plane and mid-crustal flow rotate the Franklin Mountains block.

INTRODUCTION

This paper documents and discusses the uplift of Pliocene terraces surrounding the Franklin Mountains within the southern Río Grande Rift, in far west Texas and south central New Mexico and reveals the shape of long-term extensional uplift of the terraces. The terraces along the slopes of the mountains are composed of the Fort Hancock and the Camp Rice Formations, part of the Santa Fe Group; deposition of these formations took place between 20 and 2 Ma (Gile and others, 1981; Collins and Raney, 1991)

REGIONAL SETTING

The Franklin Mountains extend from the City of El Paso, Texas on the south end into southern New Mexico (Figure 2.1). The range trends north-south and exposes Precambrian granite and metavolcanic rocks overlain by Paleozoic strata. Uplift of the mountains tilted the strata so the mountains presently dip westward at angles 40 to 80 degrees (Harbour, 1972).

The Franklin Mountains are an uplift associated with the Río Grande Rift. There are nine basins and 16 sub-basins within the Río Grande Rift (Mack and others, 1997) (Figure 2.1, Figure 2.2, and Figure 2.3). The majority of the basins of the Río Grande

Rift are half grabens that alternate orientation along the rift (Mack and Seager, 1990). Chapin and Cather (1994) propose accommodation zones as the links between the west-tilted and east-tilted basins. Figure 2.1 shows the accommodation zones that lie along the small circles of an Euler Pole in eastern Utah (Chapen and Cather, 1994).

The Tularosa and Hueco Basins combine to form a basin nearly 300 km (Figure 2.1). The Mesilla Basin is approximately 35 km wide by 100 km long. The Mesilla Basin, on the west side of the Franklin Mountains, is distinguished from the Los Muertos Basin in Mexico by a “poorly defined ground-water divide” (Hawley and Lozinsky, 1992). Mack and others (1997) also consider the Mimbres Basin west of the Mesilla Basin to be part of the Río Grande Rift. The total width of the Mimbres, Mesilla, and Orogrande Basins spans approximately 100 km.

Beginning in the Miocene, the Río Grande carried sediment from the mountains of Colorado and northern New Mexico modifying the landscape in ways important to this study. The southern part of the rift was the depositional center of this extended axial stream system and pre-existing topography was largely buried under rapidly aggrading fluvial and lacustrine sediments.

The first evidence of the Rio Grande in the southern rift near the Franklin Mountains has been dated at five Ma by using paleomagnetic reversals and dating of volcanic rocks interbedded within the sediments (Mack and others, 1998). Fluvial deposition shifted to the east side of the Franklin Mountains by two million years ago when the ancestral Rio Grande spilled through Fillmore Pass between the Organ and Franklin Mountains (Hawley and others, 1969). By the early Quaternary (2 Ma), the ancestral Rio Grande had spilled through Fillmore Pass between the Organ and

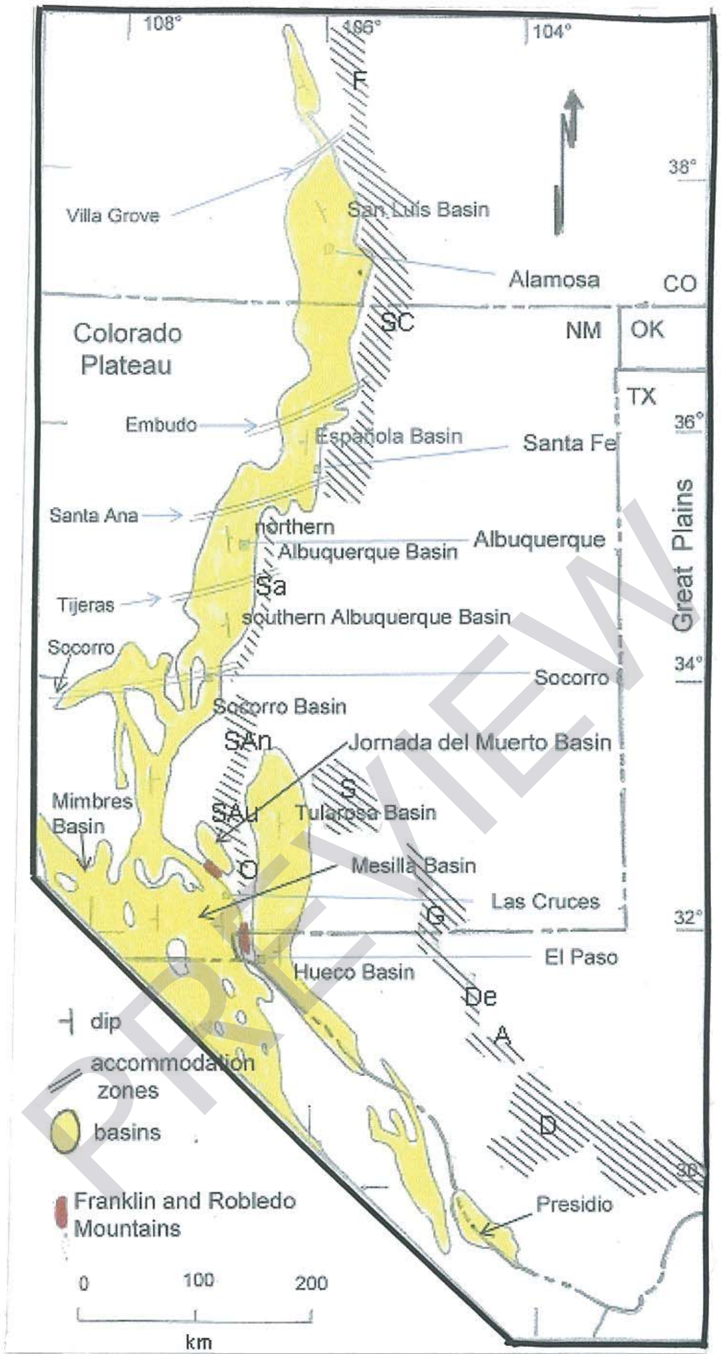

Figure 2.1 Index map (modified from Keller and Cather, 1994) of the Río Grande Rift with accommodation zones(adapted from Chapin and Cather, 1994) shown as parallel lines and traditional dip symbols displayed in the asymmetric grabens. The two areas of interest are in black. Basin bounding mountains (adapted from Armstrong and others, 2013) are: D-Davis, A-Apache, De-Delaware, G-Guadalupe, S-Sacramento, O-Organ, SAu-San Augustine, SAn-San Andres, Sa-Sandia, SC-Sangre de Cristo, F-Front Range.

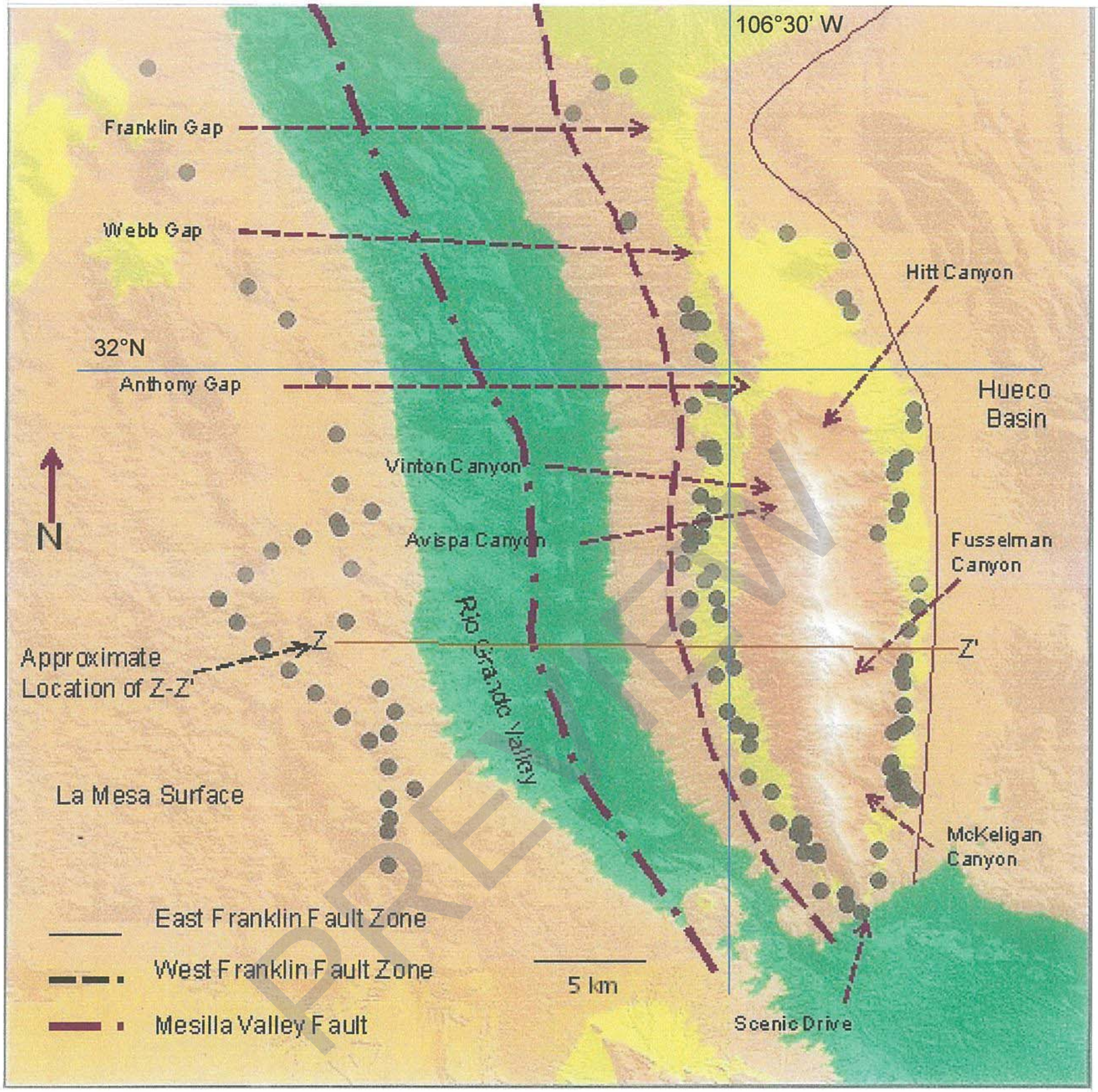

Figure 2.2. Map showing the collected points with relation to mountain. Not all points were used-higher points were replaced with lower points to avoid the influence of the alluvial fans.

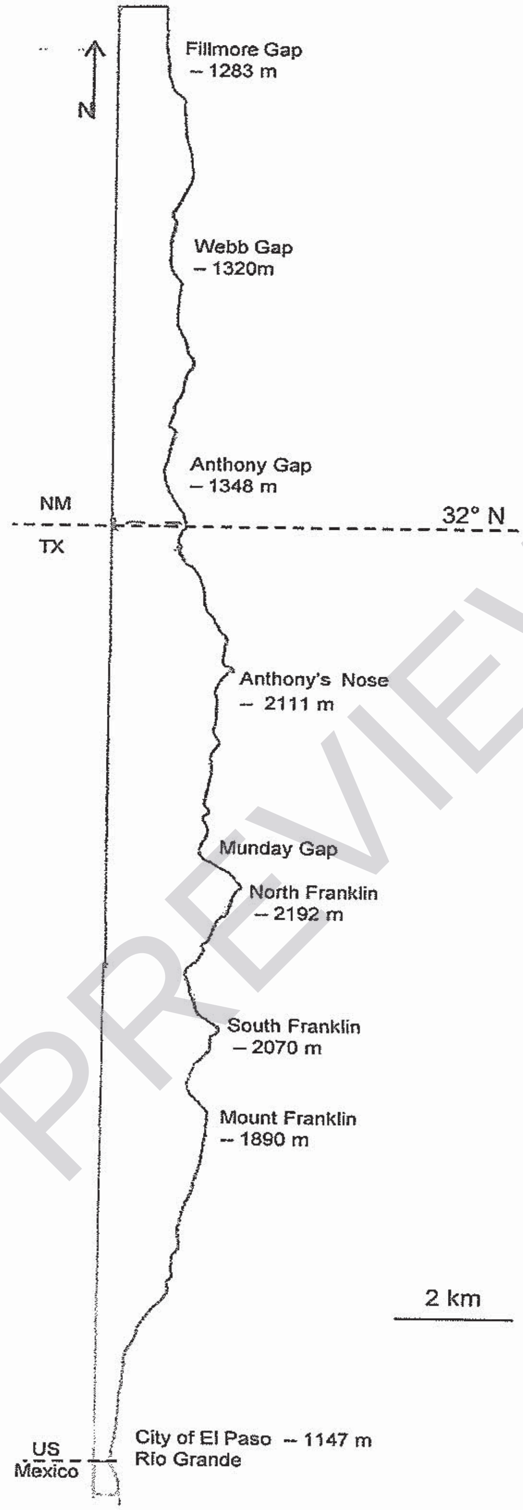

Figure 2.3. Cross-section showing the general location and elevations of the major peaks and gaps in the Franklin Mountains.

Franklin Mountains and was filling the Hueco Basin with river sediments (Hawley and others, 1969).

Deposition on the basin floors ended about 700,000 years ago (Vanderhill 1986; Mack and others, 1993; Hawley and others, 1969; Mack and others 1998; Lucas and others 1999; Gile 2007). The 640,000 year old Lava Creek Ash B is found in the oldest sediments inset into the top of the valley in Selden Canyon and El Paso Narrows, demonstrating that initial Mesilla Valley down-cutting occurred before 650,000 years ago (Izett and Wilcox, 1982; Seager and others 1984; Gile and others 1981 and 1995). The final depositional surface forms the lower La Mesa surface (Gile and others, 1981), a broad flat slope that dips southward at approximately 0.001 meter per kilometer.

FRANKLIN MOUNTAINS and EAST FRANKLIN FAULT ZONE

The Franklin Mountains are separated from the Hueco Basin to the east by the East Franklin Fault Zone. On the west, a complex of faults known as the West Franklin Fault Zone and the Mesilla Valley Fault separate the range from the Mesilla Basin (Lovejoy, 1971), (Figure 2.2). The range is cross-cut by several northwest and west trending normal faults (Lovejoy, 1975; Collins and Raney, 1991). None of these faults offsets the range-bounding faults so their movement must have ceased prior to the deposition of covering basin fill (Scharman, 2006).

The Hueco Basin (Figure 2.1) is more than 170 km long and 50 km wide, approaching three km deep near the east side of the Franklin Mountains (Collins and Raney, 1997; Averill and Miller, 2013). Numerous Quaternary faults cut the surface of

the Hueco Basin (Collins and Raney, 1994), (Figure 2.4). The fill is a combination of alluvium and Fort Hancock Formation sediments dating from 20 Ma (Gile and others, 1981; Collins and Raney, 1991) covered initially by Camp Rice Formation. Since 700,000 years ago, the basin has been weakly eroded and covered by alluvium and sand dunes.

Ramberg and others (1978) show en echelon faulting along the east side of the Franklin-Organ-St. Augustine-San Andres chain. Their data do not contain sufficient detail to distinguish small fault segments. They estimated 9.6 m of Holocene to late Quaternary slip based on a fault scarp 35 m long on the east side of North Franklin Mountain and about seven meters of slip near the south end of the Franklin Mountains.

The East Franklin Fault is the more active of the boundary faults. Studies near White Sands Missile Range indicate the last movements on the East Franklin-Organ Fault Zone occurred within the last 4000 to 5000 years (Seager, 1980). The date was determined by comparing soil development on the oldest unfaulted fan to the soil on the youngest faulted fan (Seager, 1983). Movement along the Artillery Range Fault section of the East Franklin Fault Zone may have blocked the ancestral Río Grande's course into the Hueco Basin (Mack and others, 2006).

A study of the East Franklin Mountain Fault Zone by McCalpin (2006) focused on a trench a few meters south of Hitt Canyon within three km south of the Texas-New Mexico state line (Figure 2.2). McCalpin found five normal faults, though there was uncertainty associated with the older faults. He was able to date three slip episodes using ^{14}C and compared them with infrared-simulated luminescence done on four fine, inorganic silt samples. The mean throw was 3.5 m although two paleoearthquakes