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STRUCTURE OF THE PRESIDIO BOLSON AREA, TEXAS,
INTERPRETED FROM GRAVITY DATA

by J. R. Mraz and G. R. Keller

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Cover photograph: NASA Landsat
scene 1151-16595, December 21, 1972,
Presidio Bolson area, Texas

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PLATE

1. Bouguer gravity anomaly map of Presidio Bolson study area in pocket	
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ABSTRACT

To obtain a better understanding of the structure and tectonism of the region, an integrated geophysical-geological study of the Presidio area, Texas, was undertaken using gravity measurements and deep drilling data. New gravity data were combined with existing data to construct simple Bouguer anomaly maps of the Presidio area, and two-dimensional computer modeling of gravity profiles was used to derive earth models. These data outline the major geologic features of the area that are dominated by the effects of Tertiary block faulting and volcanism. The main feature of interest was the Presidio Graben, which is approximately 1.5 km deep near Ruidosa, Texas. One motivation for this study was the collection of a part of the basic scientific data needed to assess the geothermal potential of the area, and the results obtained support the hypothesis that hot springs associated with the Presidio Graben derive their heat from deep circulation along its boundary faults. However, some gravity anomalies observed could be interpreted as indicating the presence of late Tertiary intrusions that could provide heat for the hot springs.

INTRODUCTION

The Presidio Bolson (fig. 1) is located in a graben approximately 70 km long and 20 km wide that trends north-northwest along the western edge of Presidio County, Texas, and is the dominant tectonic feature in the area. This feature, the Presidio Graben, may be a part of the southern extension of the Rio Grande Rift (Seager and Morgan, 1979) and appears to contain the most promising areas for geothermal exploration in West Texas (Hoffer, 1978; Henry, 1979). It may also be associated with significant mineral deposits (McAnulty, 1972). The Presidio Graben is bounded on the east by the Sierra Vieja, the Chinati Mountains, and the Bofecillos Mountains. The Chihuahua Tectonic Belt in the State of Chihuahua, Mexico, lies to the west of the graben. The Rio Grande runs down the center of the graben, which begins north of Candelaria, Texas, and extends south of Presidio, Texas.

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Figure 1.

The main purpose of this study was to determine the general subsurface configuration and structural setting of the Presidio Graben, thereby providing a better understanding of the tectonic and economic importance of this feature. Gravity measurements were integrated with all available geologic data to attain these goals. In addition, it was hoped that this study could provide information about the heat sources and travel paths of waters associated with hot springs in the area (fig. 1).

Several magnetic profiles were compiled using readings taken with a portable proton magnetometer. The abundant, highly magnetic volcanic rocks in the sedimentary fill along the northeast edge of the bolson (below the Sierra Vieja Rim Rock) masked magnetic anomalies related to faulting in the bolson deposits. Previous ground magnetic surveys in the Marfa Basin area (Wilson, 1951) experienced similar difficulties. Because of this problem, magnetic surveying was discontinued in favor of gravity surveying.

Gravity data collected in this study (approximately 450 readings) were combined with data from Wiley (1970), Covert (1976), and the U.S. Department of Defense gravity library (more than 2,000 readings) to produce a regional simple Bouguer anomaly map covering more than 10,000 km² (fig. 2). A more detailed simple Bouguer anomaly map (pl. I) was then produced for the immediate Presidio Graben area. Two-dimensional computer modeling (Talwani and others, 1959) of the gravity data, using existing subsurface and surface geologic data as constraints, was used to derive earth models (cross sections) along two profiles crossing the graben (fig. 1).

REGIONAL GEOLOGIC SETTING

In the northern part of Presidio County, deep drilling has penetrated Precambrian granite and arkosic sandstone (Bilbrey, 1957). These Precambrian rocks, underlying the Cambro-Ordovician Bliss Sandstone, are correlated with Precambrian outcrops in the Van Horn area to the north (fig. 1). This area was part of the Van Horn mobile belt that was intensely folded, metamorphosed, and intruded during late Precambrian time and was thrust eastward against the Texas Craton (Flawn, 1956). Subsequent erosion produced a low-relief surface gently sloping to the south. Paleozoic marine sediments were deposited upon this shelf as the Sauk Sea (Sloss, 1963) transgressed from the south.

Figure 1. (left) Index map of the study area showing locations of profiles used for gravity modeling. Hot springs and wells are indicated by stars. Features indicated by letters are as follows: a. Loma Plata Anticline, b. Rim Rock Fault, c. Candelaria Fault, d. Chinati Fault. Modified from a map kindly provided by McAnulty and McAnulty Consulting Geologists of El Paso, Texas.

Figure 2. Regional Bouguer anomaly map of the Presidio County area.

Figure 3. Locations of oil test wells in Presidio County. Numbers identify the wells as tabulated in the appendix.

In the Presidio area, Upper Pennsylvanian black shales and Permian sediments of the Marfa Basin are exposed in Laramide anticlines located in the Chinati Mountains and Pinto Canyon area (Rix, 1953). However, the best exposure of Paleozoic rocks in the region is in the Solitario Uplift (fig. 1), where Cambrian through Lower Pennsylvanian units are found. These marine sediments record a history of deposition on a stable continental shelf for most of Paleozoic time. However, in the Presidio area, the Marfa Basin was forming probably as a result of late Paleozoic tectonism associated with the Ouachita-Marathon orogenic belt to the southeast.

The Chihuahua Trough, southwest of the study area, was filling during the Jurassic and Cretaceous Periods. Jurassic evaporites were deposited in the Chihuahua Trough, but Comanchean and Gulfian sediments are the only Mesozoic rocks that have been found in the Presidio area. These units, composed of fine-grained clastics, limestones, and a basal limestone conglomerate, indicate a stable shelf area lying between the Diablo Platform and the Chihuahua Trough (Dietrich, 1965). This stability ended with Laramide thrusting and folding that formed the Chihuahua Tectonic Belt. Thrust sheets encountered in wells just north of the Presidio Graben (fig. 3, nos. 4 and 5) are a buried subsurface extension of the Chihuahua Tectonic Belt (Kopp, 1977).

The Tertiary was a time of Basin and Range normal faulting and igneous activity in the Presidio area. Tertiary volcanic rocks originated from numerous eruptive centers in a northwest-trending belt extending along the boundary region between the Diablo Platform and the Chihuahua Tectonic Belt (Barker, 1977). Several features of this belt (including the Chinati Mountains) have been interpreted as resurgent cauldrons (McAnulty, 1975). In the Presidio area, eruption began along the northeastern edge of the Sierra Vieja and Chinati Mountains 30 to 40 m.y. ago (Wilson and others, 1968) and spread southward to the Bofecillos Mountains volcanic center (McKnight, 1970). Radiometric dating (Dasch and others, 1969) establishes the presence of a second eruptive phase 18 to 23 m.y. ago (early Miocene) and through field relations dates the initiation of normal faulting in the graben area (along the Rim Rock Fault).

Normal faulting and infilling of the bolson (graben) continued until integration was accomplished by the Rio Grande (Strain, 1970), which has cut approximately 300 m into lake-bed sediments (Groat, 1972). Arroyos have revealed faults in the bolson gravels that imply some late Cenozoic movement along the Basin and Range trends. This movement could be related to the southern extension of the Rio Grande Rift into the area. However, the question of the nature and location of any extension of the Rio Grande Rift south of El Paso, Texas, is controversial (Seager and Morgan, 1979), and its answer will require additional crustal structure and heat-flow studies.

The eastern boundary fault zone of the Presidio Graben consists of the Rim Rock Fault, the Candelaria Fault, and the Chinati Fault. The Rim Rock Fault of the Sierra Vieja can be traced from the Van Horn area (fig. 1) southward to the Chinati Mountains. This high-angle, normal fault is downthrown on the west. South of Candelaria, this fault bifurcates, displaying 90 m of displacement, a decrease from 900 m observed near the abandoned town of San Carlos. The Candelaria Fault, also downthrown on the west, extends from the south end of the Sierra Vieja southward to Pinto Canyon. Displacement decreases southward from 550 to 25 m. The Chinati Fault Zone, downthrown on the west, separates the Chinati Mountains from the Presidio Bolson.

DATA COLLECTION AND REDUCTION

Surveys of small variations in Earth's gravity field have proven to be a useful and relatively inexpensive tool to determine subsurface structure. However, the

interpretation of gravity surveys requires as much geologic input as possible because of the inherent ambiguity of gravity data. In this study, geophysical and geological data have been carefully integrated, and the resulting interpretational models should be considered geologic cross sections constructed with the aid of computer modeling of gravity data.

During this study, gravity readings were collected in a standard closed-loop pattern so that drift corrections could be calculated. All readings were referenced to the International Gravity Standardization Net, (IGSN) 1971, network of base stations (Morelli, 1976) through secondary base stations tied to the U.S. Department of Defense base station at Alpine, Texas (DOD 595-2).

Gravity stations were established at bench marks and spot elevations on topographic maps to ensure the accuracy of both horizontal and vertical control. Station spacing was largely dictated by land access and the availability of elevation data.

Standard corrections to the gravity data were made by computer. In addition to the drift correction, the standard corrections include a two-part elevation correction and a latitude correction. Terrain corrections, if deemed necessary, are usually calculated separately because of the tedious procedure involved. In this study, terrain corrections were calculated using the method of Hammer (1939) and were made only for gravity stations used in constructing the gravity models.

The two-part elevation correction includes the Bouguer and Free Air corrections and is designed to remove predictable gravity variations caused by elevation changes. The Free Air correction accounts for the gravitational variation between the station elevation and the datum elevation. The Bouguer correction removes the effect of the mass of material between the station elevation and the datum plane. A sea-level datum and the standard Bouguer density value of 2.67 g/cm^3 were used for the elevation correction.

In general, the value of gravity increases in a predictable pattern with distance from the Equator. To remove the effect of these variations, latitude corrections were accounted for by calculating theoretical gravity at each station using the International Gravity Formula of 1967 (Morelli, 1976).

The goal of these corrections is for the resulting values to reflect as much as possible only geologically meaningful variations in gravity. In this study, the usual sources of error (nonlinearities in meter drift, Earth tides, reading error, and elevation inaccuracies) yield readings that are estimated to be accurate to within $\pm 0.5 \text{ mgal}$.

GRAVITY ANOMALIES OBSERVED

The major geologic features in the region are represented by recognizable anomalies on the regional gravity map (fig. 2). The Chihuahua Tectonic Belt (Sierra Grande and Sierra Pilares) west of the Presidio Graben is represented by a northwest-trending linear gravity maximum. The Presidio Graben is associated with a gravity low approximately aligned with the course of the Rio Grande. A gravity low is centered on the Presidio/Jeff Davis county line south of Valentine (fig. 2) and is interpreted to represent the Valentine Basin (Covert, 1976), which is probably a Cenozoic graben. The relatively small Redford Bolson is located south of Presidio along the course of the Rio Grande. This bolson along with the Presidio Bolson can be interpreted to be contained within a single major feature, the Presidio Graben.

An extensive gravity high is located in the area of the Bofecillos Mountains northeast of Presidio. North of this high, a gravity low trends east-west across the center of the map (fig. 2). This low probably represents the Paleozoic Marfa Basin, which in the area of the Chinati Mountains has been obscured by Laramide deformation, Basin and Range faulting, and Tertiary volcanism. The Chinati Mountain gravity high flanks the east side of the Presidio Graben and appears to extend northward into the Sierra Vieja gravity high.

The gravity signature of the Presidio Graben was interpreted using the detailed map of the area (pl. I) and computer modeling along the two profiles discussed in the next section. The graben, 70 km long and 15 to 20 km wide, is deepest (approximately 1.5 km) in the Ruidosa area. The higher gravity gradient on the graben's west side (in Mexico) indicates that this side is more steeply faulted than the eastern side. Sedimentary fill in the Presidio Bolson thins north of Ruidosa and pinches out south of Candelaria. However, a gravity low continuing 15 km north of Candelaria (pl. I) indicates the extent of the graben. The bolson fill is thickest in the area immediately south of Ruidosa. Farther south, the subsurface structure of the graben is apparently simple, and the fill thins gradually before merging into the Redford Bolson approximately 15 km south of Presidio.

The gravity data suggest a complex subsurface structure in the Ruidosa area. However, this interpretation is equivocal because the geologic setting suggests that significant volumes of volcanic rock lie beneath the bolson fill in this area and could be responsible for this complexity. Tertiary intrusions similar to those found northwest of the Loma Plata Anticline (Amsbury, 1958) could also produce the small gravity anomalies seen in this area. Delineation of the details of the subsurface structure of this area must await further drilling information.

Three prominent local anomalies (two gravity lows bracketing a gravity high) are located between Capote Peak and Candelaria (fig. 1). Because of the significant topographic relief in the area, terrain corrections were calculated for selected gravity stations. These anomalies are too large to be simply the result of terrain effects because the maximum terrain correction calculated was 11 mgal and most were much smaller. Step faulting of Tertiary volcanics into the bolson and Laramide structures trend north-south in this area. Thus, these northeast-trending features may reflect Paleozoic structures related to those in the Marathon region to the east.

COMPUTER MODELING

Computer modeling of observed data is a major interpretational tool in gravity studies. The two-dimensional modeling technique used in this study (Talwani and others, 1959) calculates the theoretical gravitational attraction of horizontal prisms of infinite lateral extent. An earth model is constructed using these prisms, which, when displayed in cross section, appear as polygons. The attraction of each prism at each point is calculated, and the fit of the theoretical and observed data is displayed. The geometry and density of the prisms are altered until the theoretical and observed data agree.

Well data served as a valuable constraint in the gravity modeling along with surficial geologic data. Well data collected for this study are shown in figure 3 and tabulated in the appendix. A comprehensive review of previous geologic studies can be found in Kopp (1977) and in Henry (1979). Considering the data resolution and the available geologic control, only the following geologic units were modeled: bolson fill (1.9 g/cm^3), Tertiary volcanics (2.0 g/cm^3), Tertiary intrusives (2.65 g/cm^3), Paleozoic sediments (2.6 g/cm^3), and the Precambrian basement (2.7 g/cm^3). Because no bulk density logs were available for Presidio County, these density values were chosen on the basis of measurements reported by Healey (1970) (bolson fill and Tertiary volcanics) for a geologically similar area of Nevada and by Wilson (1951) (Cretaceous and Paleozoic sediments) for the Marfa Basin area. The lack of density information limits the resolution of the gravity interpretation.

Both earth models extend to a depth of 8 km below the datum elevation. The datum plane elevation was the elevation of the lowest gravity station on each profile (783 m for the Shafter Highway profile; 795 m for the Pinto Canyon profile). It is important to note that normal faulting in the Presidio area has downdropped Paleozoic and Cretaceous rocks so that at depth in the graben these units are probably adjacent to higher density basement rocks. Thus, some of the negative anomaly associated with the graben would be a result of a negative density contrast associated with these units.

On the Pinto Canyon profile (A-A', figs. 1 and 4) the Chihuahua Tectonic Belt in Mexico is represented by a gravity high, whereas the Presidio Bolson is manifested by a gravity low. The Gulf Oil test well (appendix, no. 6) located 5.6 km south of the profile was cased to a depth of 975 m. This value is interpreted as the depth of bolson fill at this point since formation contact depths were not released for this well. This interpretation is based on the assumption that casing could have been necessary to prevent caving and lost circulation of drilling mud in the highly permeable fill. However, many wells in Presidio County were cased through Tertiary tuffaceous rhyolites, and it is therefore possible that part of what has been interpreted as 975 m of bolson fill could be Tertiary volcanics.

Along this profile, the Candelaria Fault forms the eastern boundary of the graben. The gravity high in the vicinity of the Sierra Vieja represents a shallowing of the Precambrian basement and/or an intrusion. Linear gravity trends east of this high indicate an eastern boundary fault for the Sierra Viejas. The gravity low, east of the Sierra Vieja, is apparently associated with the Marfa Basin. Northeast of the Marfa Basin, the Valentine Basin (Covert, 1976) is represented by another gravity low. The intervening gravity high represents a ridge in the basement that trends northwest-southeast. In the Marfa area, Gulf's H. J. Hubbard well, Phillips' 1-C Mitchell well, and Tucker's H. B. Holmes well (appendix, nos. 14, 13, and 12) indicate the Tertiary volcanics to be at least 500 m thick. The Davis Mountains, which are the probable sources for these volcanics, are represented by a slight gravity low.

On the Shafter Highway profile (B-B', figs. 1 and 5), the Paleozoic Marfa Basin is represented by a gravity low south of Marfa, Texas. This basin thins southward toward the Chinati Mountain gravity high near Shafter, Texas. The West-Cockburn's No. 1 Presidio Trust well (appendix, no. 26), 26 km north of Presidio, encountered at least 1 km of bolson fill before bottoming in limestone, as did West's No. 1 Presidio Trust well (appendix, no. 25) and Atlantic Richfield's Presidio State well (appendix, no. 22), 7 and 9 km north of Presidio, respectively. The bolson is deepest (1.2 km) on this profile in the immediate vicinity of Presidio. A gravity high representing the Chihuahua Tectonic Belt is encountered to the south in Mexico.

IMPLICATIONS FOR GEOTHERMAL RESOURCES

The Presidio Graben is comparable in extent (70 by 20 km), trend (northwest), and gravity relief (-30 mgal) to typical Basin and Range grabens (Thompson, 1959) and is clearly a major structural feature. Also, as discussed in detail by Henry (1979), this feature contains numerous hot springs that are associated with its boundary fault

Figure 4. Gravity-structural cross section along profile A-A' (Pinto Canyon Highway profile). Numbered triangles refer to wells identified in the appendix. Density values (g/cm^3) are given in parentheses following boxes.

Figure 5. Gravity-structural cross section along profile B-B' (Shafter Highway profile). Numbered triangles refer to wells identified in the appendix. Density values (g/cm^3) are given in parentheses following boxes.

zones. Gravity data and computer modeling (figs. 3 and 4) demonstrate that these fault zones extend to depths of approximately 5 km. However, the correlation between the deep faults and mapped surface faults is only approximate; major faults extend outside the area of bolson fill.

At least four heat sources have been proposed to explain the hot springs associated with the Presidio Graben:

- (1) Conversion of gypsum to anhydrite in thick evaporite sequences.
- (2) Migration of hot waters from the Chihuahua Trough.
- (3) Magmatic heat from recent igneous activity.
- (4) Deep circulation of waters in an area of relatively high geothermal gradient.

The conversion of gypsum to anhydrite involves an increase of density, but without well control, the gravitational signature of this change would probably be difficult to detect. However, the well data available do not indicate the presence of large quantities of evaporites near the graben. Large quantities of evaporites are found to the southwest in the Chihuahua Trough (J. Tovar, personal communication, 1979), but there is no evidence for large-scale conversion of gypsum to anhydrite. Also, to account for the hot springs on the east side of the Presidio Graben, any heat generated in the vicinity of the Chihuahua Trough would have to migrate updip over 100 km (probably along thrust faults), cross the deep-seated western boundary fault of the graben, pass beneath the graben (through an area that is probably highly fractured), and surface along the eastern boundary fault of the graben. Thus, it seems more likely that most water migrating from the Chihuahua Trough would either disperse or find its way to the surface before reaching the eastern boundary fault of the graben. However, most of the hot springs in the area are found along the eastern boundary fault of the graben rather than in areas to the southwest.

Heat could also be provided by recent igneous activity, and several gravity anomalies in the Ruidosa area could be the signature of intrusions. However, there is no geologic or geochronologic data to suggest igneous activity younger than 15 m.y. Thus, any intrusions present have probably already cooled.

Henry (1979) concludes that deep circulation in an area of relatively high geothermal gradient is the most likely source of heat for the hot spring activity. The results of this study indicate that the boundary fault zones of the Presidio Graben are deep seated, extending to approximately 5 km. Although this depth estimate is imprecise, there is little doubt that these faults could easily act as conduits for deep circulation. Even with conservative estimates for the depths (3 km) and geothermal gradient ($30^{\circ}\text{C}/\text{km}$), temperatures of near 100°C seem reasonable.

CONCLUSIONS

1. The Presidio and Redford Bolsons are located in a major Basin and Range structure--the Presidio Graben.
2. The northern part of the graben (from Ruidosa northward) is structurally complex and contains northeast-trending (late Paleozoic) and northwest-trending (late Mesozoic and middle Tertiary) structures; however, to the south, the subsurface structure appears to be relatively simple.
3. The fill in the Presidio Bolson is more than 1 km thick in several localities and is thickest in the Ruidosa area, where it is approximately 1.5 km thick.
4. Local gravity features in the northern part of the graben could be associated with unexposed Tertiary intrusions.
5. The results of this study show that the graben's boundary fault zones are major deep-seated features and support Henry's (1979) conclusion that deep circulation along these faults is the most feasible explanation for the hot springs in the area.

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APPENDIX: WELL DATA IN PRESIDIO COUNTY AREA

Index no.	Well name and company	Date completed elev. spudded total depth (ft)	Source	Unit thickness (ft)
1	Gulf Oil Corp., #1 Trust Nat'l. Bank of Fort Worth	4-15-64 ---- 11,701	Kopp (1977)	----
2	Stanolind Oil, Trust #1	8-15-45 3,858 8,111	Carlisle (1955)	Cret. 5,770 Paleo. 2,250 Granite 90+
3	N. B. Hunt #1 Toole Trust	7-14-53 3,858 8,111	Bilbrey (1957) Midland Sample Library	Alluvium 1,610 Cret. 4,160 Paleo. 2,230 Granite 110+
4	Gulf Oil, #1 Swafford NCT-A	1-5-64 3,456 8,815	Kopp (1977) Midland Sample Library	Tert. Vol. 1,455 Cret. 1,100 U. Paleo. 5,935 Camb.-Ord. 320 Granite 5+
5	Gulf Oil Corp. Presidio Trust "3" #1	5-7-64 3,239 6,208	Kopp (1977)	----
6	Gulf Oil Corp. #1 State School Board "LO"	9-13-55 ---- ----	Kopp (1977) Tops picked by J. M. Hills	Bolson Fill 3,200 Cret. 2,970 Paleo. 3,270+
7	Brite Fee #4	11- -38 5,255 ----	Carlisle (1955) Midland Sample Library	Tert. Vol. 1,390 Cret. 3,750+
8	Lewis W. Welch, #1 Jos. Espy	8-2-52 4,746 7,837	Carlisle (1955) Midland Sample Library	Tert. Vol. 3,390 Cret. 1,750 U. Paleo. 1,130 Ord. 510 Camb. 490 Prec. 100+
9	Brite Fee #1	2-26-53 ---- 5,126	Carlisle (1955)	Tert. Vol. 2,410 Cret. 2,746+
10	Sinclair Oil and Gas Co., #1 Evans	10-5-62 4,673 ----	Kopp (1977) Midland Sample Library	Tert. Vol. 4,780 Cret. 4,640+

Index no.	Well name and company	Date completed elev. spudded total depth (ft)	Source	Unit thickness (ft)
11	O. N. Beer Inc., #1 Robert R. York "OWDD"	6-1-66 4,669 6,903	Kopp (1977)	Tert. Vol. 4,250 Cret. 0 Paleo. 2,650+
12	Tucker Drlg. Co. Inc., #1 H. B. Holmes, Jr.	4-9-68 4,744 6,020	Kopp (1977)	Tert. Vol. 3,960 Cret. 2,060+
13	Phillips Pet. Corp. #1-C Mitchell	10-13-71 4,550 8,584	Petroleum Inf. Corp.	Tert. Vol. 400 Cret./Paleo. 4,585+
14	Gulf Oil Corp., #1 H. J. Hubbard	2-12-61 4,587 10,132	Paleo. Lab., Midland (tops)	Tert. Vol. 3,970 Cret. 0 Perm. 4,040 Miss. 120 Dev. 230 Sil. 600 Ord. 1,170
15	Sinclair Oil & Gas Co., #1 Allison	12-18-64 5,100 6,010	Williams and Lee Scouting Service, Inc.	Tert. Vol. 910 Cret./Paleo. 5,100+
16	Socony Mobil Oil Co., Inc., #1 J. E. White & Sons	4-6-61 4,596 4,570	Geol. Inf. Center, Midland	Tert. Vol. 1,445 Cret. 3,120 Granite 5+
17	The Pure Oil Co., #1 J. F. Lane	6-24-61 4,000 7,908	Paleo. Lab., Midland	Tert. Vol. 3,460 Cret. 360 Perm. 880 Dev. 70 Sil. 870 Ord. 1,290+
18	El Paso Natural Gas Co., #1 Simpson	1-29-72 ---- ----	Kopp (1977)	Tert. Vol. 2,610 Cret. 1,540 Perm. 6,655 Penn. 365 Miss. 110 Sil./Dev. 735+
19	Gulf Oil Corp., Arco-Mitchell #1	1-9-47 5,338 15,996	Carlisle (1955) Midland Sample Library	Tert. Vol. 2,250 Cret. 680 Perm. 9,700 Miss. 810 Dev. 385 Ord. 1,410+

Index no.	Well name and company	Date completed elev. spudded total depth (ft)	Source	Unit thickness (ft)
20	Exxon Corp., #1 J. P. Kennedy	9-1-74 ---- 19,739	Geol. Inf. Center, Midland	----
21	Pan Amer. Pet. Corp., #1 Moody-Hutchings	9-25-62 ---- 9,256	Kopp (1977)	----
22	Atlantic Richfield, #1 Presidio State	11-19-76 ---- 8,500	Kopp (1977)	Bolson Fill 3,385 Cret. 4,595 Perm. 520+
23	Linderman Bros. Oil Corp., #1 Bledsoe	---- ---- 507	Kopp (1977)	----
24	Linderman Bros. Oil Corp., #1 Bledsoe & Bagley	---- ---- 3,312	Kopp (1977)	----
25	Wesley W. West, #1 Presidio Trust	11-7-48 2,870 8,002	Zinn (1953)	Bolson Fill 3,225 Cret. 4,780+
26	Wesley W. West and Cockburn, #1 Presidio Trust	5-4-50 3,469 8,774	Zinn (1953)	Bolson Fill 3,460 Cret. 5,320+
27	Wesley W. West, #1 R. I. Bledsoe	2-11-54 2,738 12,499	Geol. Inf. Center, Midland	----
28	E. W. Hazelwood/ H. C. Lasley, #1 T. L. Davis	7-1-56 ---- 2,200	Kopp (1977)	Bolson Fill 1,100 Anhydrite 1,100
29	Fairway Oil & Gas Co., Inc., #1 S. W. Birdsal	4-10-67 3,761 6,571	Kopp (1977)	Cret. 1,500 Paleo. 5,020
30	Gulf Oil Corp., CT-1 State Nat'l. Bank of El Paso	---- 3,297 ----	Petroleum Inf. Corp., Midland	----
31	Phillips Petroleum Co., Tootle #1	---- ---- 4,732	Bilbrey (1957)	Alluvium 30 Cret. 4,700

Index no.	Well name and company	Date completed elev. spudded total depth (ft)	Source	Unit thickness (ft)
32	Texas and Pacific Coal, Bagle #1	---- 4,665 5,290	Carlisle (1955)	Tert. Vol. 2,280 Cret. 450 Perm. 1,560+
33	Lewis W. Welch #1 Brite	2-26-53 5,058 6,135	Carlisle (1955) Midland Sample Library	Tert. Vol. 3,170 Cret. 820 U. Paleo. 740 Ord. 1,270 Camb. 135+
34	Wilcox-Presidio, Corning #1	---- 4,300 8,523	Carlisle (1955)	Tert. Vol. 2,270
35	Killam Deep Test	---- ---- 8,370	Woodward (1954)	Alluvium 587 Tert. Vol. 5,970 Cret. 1,800

EXPLANATION
 --- Primary contour line, dashed where data lacking
 --- Secondary contour line
 --- Paved road
 --- Gravel road
 • Gravity station

PLATE I. BOUGUER GRAVITY ANOMALY MAP OF PRESIDIO BOLSON STUDY AREA, PRESIDIO COUNTY, TEXAS.