WEST TEXAS GEOTHERMAL RESOURCE ASSESSMENT 34

PART I 24

GEOTHERMAL EXPLORATION IN TRANS-PECOS, TEXAS 34

by

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Executive Summary

Knowledge of the thermal regime in Trans-Pecos Texas has been slow to accumulate, despite the presence of several interesting natural geothermal phenomena. These occur mainly within the Rio Grande Valley between El Paso and Big Bend National Park, and consist mainly of hot springs and hot wells. Present limited heat-flow data suggest an increased heat-flow in the river zone, as compared with the high plains to the east. A series of 67 gradient holes measured largely in Presidio county also support this observation. Twenty gradient holes measured in the high plains have an average gradient of about $30^{\circ}\text{C}/\text{km}$; forty seven gradient holes measured in the Rio Grande Valley area have an average gradient of about $77^{\circ}\text{C}/\text{km}$. These results correlate well with the silica geothermometry studies of Hoffer (1979).

All of the new drilling for geothermal gradient and heat flow studies have been concentrated in an area near Hueco Tanks State Park. Interest in the area was raised by the silica geothermometry map of Hoffer (1979) and its proximity to El Paso, which is less than 25 miles away and expanding rapidly toward the area of geothermal interest. Several industries in El Paso appear to be potential users of non-electrical grade hot waters. A total of 14 holes have been drilled for geothermal gradient and heat-flow measurements. Of these, 12 were 50 meters deep and all but two had gradients in excess of $100^{\circ}\text{C}/\text{km}$, one having a gradient as high as $306^{\circ}\text{C}/\text{km}$. Of the remaining two, one penetrated bedrock at about 50 meters and was drilled to a total depth of 125 meters. The gradient in the limestone bedrock is $170^{\circ}\text{C}/\text{km}$ and the heat flow is about $11 \times 10^{-6}\text{cal}/\text{cm}^2 \text{ sec}$. This is the highest heat flow thus far reported for a locality in the Rio Grande Rift. The last hole is 300 meters deep and has a gradient of $142^{\circ}\text{C}/\text{km}$ and a heat flow of $9 \times 10^{-6}\text{cal}/\text{cm}^2 \text{ sec}$.

The Hueco Tanks site is very promising for at least space heating applications of hot water. Based on the 300 meter hole the potential for electricity grade temperatures still exist, but the tight limestone bedrock may require hot dry rock extraction technology.

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INTRODUCTION

Previous work has been accomplished within the Trans-Pecos Texas/New Mexico area by various researchers. Geothermal prospecting has been somewhat limited, partly by the remoteness of the country, and partly by the lack of a ready market for any non-electrical grade resource.

Present heat-flow data in West Texas are sparse; up to now, efforts in the region have been mainly concentrated north of the Texas-New Mexico border, in defining the thermal characteristics of the Rio Grande Rift. Herrin and Clark (1956) determined the heat-flow in the Permian Basin oil fields to be 1.1 h.f.u. (1 h.f.u. = 10^{-6} cal/cm²s), typical of the Great Plains province, while the results of Decker and Smithson (1975) in southern New Mexico and West Texas reflect the normal heat-flow of the Basin and Range province (about 2.0 h.f.u.). This suggests, as does the surface geology, that Trans-Pecos is a transition zone between these two provinces.

Geochemical survey work by Hoffer (1979) identified several areas in West Texas that may have potential for the development of geothermal resources. Hoffer's study area included El Paso, Hudspeth, Culberson, Jeff Davis, Presidio and Brewster Counties. Water samples were collected from all available springs and wells in the area, a total of more than 1000 being taken and analyzed during the course of the survey. The primary interpretative tool used was the silica geothermometer described by Fournier and Rowe (1966), in which silica concentrations are used to estimate reservoir temperatures. Some of Hoffer's (1979) results are reproduced in Figure 1; the most promising geothermal areas indicated here,

Figure 1. Silica geothermometer temperatures, Trans Pecos, Texas. After Hoffer (1979).

according to the silica geothermometer, are near Hueco Tanks State Park (about 25 miles east of El Paso) and in northern Presidio County. A more detailed map of the Hueco Tanks area along with the locations of the boreholes used in this study is shown in Figure 2.

Henry (1978) made a study of the geologic setting and geochemistry of thermal waters in the western Trans-Pecos area, in particular the Rio Grande Valley in Presidio County and adjacent Mexico, which contains several hot springs and wells (Figure 3). Temperatures are varied, but the hottest spring activity (89°C) in the whole Rio Grande Rift occurs in Mexico, just three miles southwest of the river settlement of Candelaria. The Gulf Oil Corporation drilled two wells in 1965, which encountered a hot-water aquifer at a depth of about 1000 meters; the wells are artesian and discharge at 72°C and 69°C , respectively. (Discussions with a former board member of the Rio Grande Electric Cooperative have revealed that Gulf, which took out geothermal leases in this area in the early 1970's, indeed found a promising geothermal potential here; there are unconfirmed reports of steam issuing from their test-holes, which are now unfortunately plugged.)

Two hot springs have been developed as small health resorts, the first commercial use of geothermal waters in the region. The springs emanate from Quaternary bolson fill, and are almost certainly connected with the north-south trending boundary faults which define the eastern edge of the river valley. This "rim" is marked by fault scarps of Tertiary basalt and ash flows, interspersed with intrusive centres of similar age; the downdropped (west) side is covered by bolson deposits, which gravity modelling has shown to attain a maximum thickness of 1.5 km (Mraz, 1977).

Figure 2. Location of gradient holes near Hueco Tanks. Gradients are in °C/km. Silica temperature contours after J.M. Hoffer (1979). The large dot with a gradient of 170°C/km penetrated bedrock, the heat flow is 11 h.f.u. The large dot with a gradient of 142°C/km also penetrated bedrock, the heat flow is 9 h.f.u.

Similar graben structures exist further north, in the form of the Salt Flat Graben and Hueco Bolson, both east of El Paso, the second of which contains an area under present investigation for geothermal resources. A generalized tectonic map of Trans-Pecos Texas, showing the above features, is presented in Figure 4.

DESCRIPTION OF PROJECT, AND DATA OBTAINED.

The technical assessment of potential geothermal resources - their nature and extent - has to date been carried out by the University of Texas at El Paso. In addition to this, the T.E.A.C. study has included a utilization study by Energy Policy Studies Inc., under the auspices of Southwest Research Institute, and an investigation of the legal aspects of geothermal development by the Texas General Land Office. The primary objectives of the project were to further delineate the regional heat-flow pattern and to investigate specific areas with a view to their geothermal energy potential.

GEOHERMAL GRADIENT AND HEAT-FLOW MEASUREMENTS.

For any energy resource to be economically viable, it must be readily accessible to the user. With this in mind, it was proposed to investigate the possible existence of a geothermal resource in El Paso. The University of Texas at El Paso is built on a geological formation known as the Campus Andesite, one of several small Tertiary igneous intrusions in the Rio Grande Valley on the western side of the city; a sufficiently high thermal gradient in this unit would indicate that the andesite may be hot enough, at depth, to support a hot-dry-rock energy extraction scheme. A 120 m hole was drilled,

Figure 4. Generalized tectonic map of Trans-Pecos, Texas.

therefore, to establish the geothermal gradient, but when measured, it was found to be normal at $33^{\circ}\text{C}/\text{km}$; the heat-flow was calculated to be 2.1 h.f.u., again normal for the Basin and Range province.

A series of about 70 geothermal gradient measurements have so far been made in abandoned boreholes and wells in El Paso, Hudspeth, Culberson, Presidio and Brewster Counties; some 70% of the data collected to date comes from the Presidio Bolson, in which much of the hot spring activity is located. The data is presented in Figure 5. In general, it is apparent that gradients are higher on the downthrown side of the boundary faults, in the Rio Grande Valley, than they are on the "top" side. They are particularly high in the vicinity of some of the springs (several being over $100^{\circ}\text{C}/\text{km}$). Figure 6 is a plot of bottom-hole temperatures versus depth in those boreholes. The points are distinguished as those occurring above (i.e. east of) the boundary faults and those below (in the Rio Grande Valley). Although somewhat scattered, the two sets of points remain separately zoned; least-squares lines through them give regional gradients of $30^{\circ}\text{C}/\text{km}$ above the bolson, and $77^{\circ}\text{C}/\text{km}$ in the valley (the solid line in Figure 4 represents the boundary between these two gradients, albeit conjectural in the northern part of the region). This marked difference may reflect the previously mentioned junction between the Basin and Range and Great Plains tectonic provinces. It may later be possible to extend southwards a crustal-thinning model similar to that of Decker and Smithson (1975) into the present area of interest, to explain the high gradients.

Figure 2 (after Hoffer, 1979) reveals an anomaly in northern El Paso County which extends into Otero County, New Mexico. Here, the SiO_2 geothermometer

Figure 6 Bottom hole temperatures in the Presidio Bolson plotted against depth. The boreholes east of the boundary faults have an average gradient of $30^{\circ}\text{C}/\text{km}$. The boreholes in the Rio Grande Valley have an average gradient of $77^{\circ}\text{C}/\text{km}$.

predicts source temperatures in excess of 140°C . The Hueco Tanks site, as we have called it (from its proximity to the State Park of that name), is about 25 miles east of El Paso, and could thus, if proven, provide an energy source to a city which is already rapidly expanding towards it. Current exploration efforts are therefore directed towards an evaluation of this prospect. A series of 50 m boreholes has been drilled across the geochemical anomaly (twelve holes in all); they reveal abnormally high gradients over the anomaly, increasing from $106^{\circ}\text{C}/\text{km}$ on the west to $280^{\circ}\text{C}/\text{km}$ in the east. Holes drilled a little to the south of the silica high have somewhat lower gradients (though still three to four times normal), which is well in keeping with the pattern predicted by the silica temperature contours (Figure 2). Two more holes sited off to the west and east of the anomaly have gradients of $34^{\circ}\text{C}/\text{km}$ and $56^{\circ}\text{C}/\text{km}$ respectively, thus fulfilling their purpose of delineating the edges of the area of high thermal gradient. Further, an abandoned well, seven miles to the southwest, yielded a "normal" gradient of $42^{\circ}\text{C}/\text{km}$. As is the case in Presidio County, the Hueco Tanks site is situated at the faulted eastern margin of a graben, this time the Hueco Bolson, an alluvium filled structure reaching a depth of over 2 km to the west of the site (Davis and Legget, 1967). All of the 50 m holes are therefore in bolson-fill, but two deeper holes (125 m and 300 m), two miles to the southeast of the main geochemical anomaly, penetrated Permian limestone (a downdropped fault-block from the nearby Hueco Mountains), and the high geothermal gradient continues into this medium. (The drilling of these two latter holes was prompted by a gradient of $252^{\circ}\text{C}/\text{km}$ in an abandoned well nearby.) Thermal conductivity measurements made on the core from these holes yielded heat-flows of 11 h.f.u.

(170°C/km bedrock gradient) and 9 h.f.u. (142°C/km bedrock gradient) respectively. The locations and data for all the gradient holes are superimposed on the silica temperature contours in Figure 2. All the temperature-depth curves are included in the Appendix.

OTHER GEOPHYSICAL STUDIES.

The regional gravity map for West Texas (Keller et al, 1978; figure 7) reveals well the graben structures in which the geothermal manifestations occur (Presidio and Hueco Bolsons) but has insufficient detail for useful correlation. A detailed gravity survey was undertaken at Hueco Tanks, and is partially complete; the resulting Bouguer anomaly map is shown in Figure 8, along with the locations of the gradient holes and resistivity lines (see below). The map shows a discrete gravity "high" running approximately north-south, which is crossed by a northwest-southeast "low" (3 mgal total relief); the highest geothermal gradients occur at the crossover of these two features. Without proper modelling, an initial interpretation would seem to be that the diagonal "low" represents a major fault (or fault zone), up which hot water is probably rising from depth.

As mentioned, two electrical resistivity soundings have also been made in the neighbourhood of the gradient holes. They show a thin resistive overburden covering 400-500 metres of low resistivity (8-9 Ω -m) material, which is probably water saturated alluvium and limestone; this is underlain by a highly resistive "basement". The results of the two soundings are shown in figures 9 and 10.

Brief (one week) micro-earthquake recordings were made both at Hueco Tanks and Near Ruidosa Hot Springs in the Presidio Bolson. Three Sprengnether

Figure 7
REGIONAL BOUGUER GRAVITY MAP
OF
TRANS-PECOS TEXAS

CONTOUR INTERVAL 5mgal
— SEA LEVEL—DATUM
BOUGUER DENSITY 2.67 gm/cc

STATUTE MILES
KILOMETERS

Figure 8. Bouguer gravity map of Hueco Tanks geothermal area. Contour interval, 1 mgal. Resistivity soundings marked with black lines. Numbered circles refer to gradient holes (in Appendix)

HOT WELLS - LINE#1, NO. 11

MODEL PARAMETERS

R (OHM. M)	D (M)
65.0	0.5
125.0	1.5
35.0	15.0
45.0	35.0
8.0	500.0
260.0	

+ OBSERVED
 □ CALCULATED

RESISTIVITY (OHM-M) - (HMD) Y TIVITIS123A

HOT WELLS - LINE#2

MODEL PARAMETERS

R (OHM.M)	D (M)
85.0	0.9
180.0	5.0
9.0	400.0
340.0	

+ OBSERVED
 □ CALCULATED

Figure 10 Schlumberger sounding #2 near Hueco Tanks.

MEQ 800 micro-earthquake recorders were deployed in triangular arrays, in each case. The purpose of such recordings is to locate active faults which might be conduits for rising hot waters. No events were recorded at Hueco Tanks in the time allowed; two events, apparently associated with the Rim-Rock fault, were recorded at Ruidosa Hot Springs.

UTILIZATION STUDIES.

Gilliland et al (1979) have examined possible usage of both electrical and non-electrical grade geothermal resources, in particular with reference to the Hueco Tanks area. Five industries were identified for potential direct-heat applications: meat packing, dairy, soft-drink bottling, canning and apparel. Space heating applications were also considered. Because of the sparsity of population in the Presidio area, electricity generation emerged as the major geothermal application there, with local space-heating where feasible or necessary. Details of this study are included in Part II of this report.

CONCLUSIONS AND RECOMMENDATIONS

Based on the geothermal gradient measurements, both the Hueco Tanks site and the Presidio Bolson show sufficient promise to encourage more exploration. The Hueco Tanks study should be extended to the north into Otero County, New Mexico where the highest silica geothermometer temperatures have been found. This will require both additional funding, which has been applied for, and permission from the Army to work on Fort Bliss. Hoffer (personal communication, 1979) had no difficulty in obtaining permission from the Army in his efforts to obtain water samples from wells on Fort Bliss. It remains to be seen if they will be equally cooperative about a drilling project. Drilling is proposed for twelve more 50 meter gradient holes, three

300 meter heat flow holes, and if the high gradients persist in one or more of the 300 meter holes, a 750 meter deep test at Hueco Tanks. In the Presidio Bolson, probably in the area of Ruidoso Hot Springs, drilling is proposed for ten 50 meter gradient holes and one 300 meter heat flow hole.

The Campus Andesite presently shows no potential for geothermal energy production.

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Appendix
Geothermal Gradients, Hueco Tanks
(Locations keyed to Figure 8)

GEO THERMAL GRADIENT
HUECO TANKS #1, EL PASO (WESTEX 56)

TEMP., DEG.C

GEO THERMAL GRADIENT
HUECO TANKS #2, EL PASO (WESTEX 57)

TEMP., DEG.C

GEO THERMAL GRADIENT
HUECO TANKS #3, EL PASO (WESTEX 58)

TEMP., DEG.C

GEOTHERMAL GRADIENT
HUECO TANKS #4, EL PASO (WESTEX 59)

TEMP., DEG.C

GEO THERMAL GRADIENT
HUECO TANKS #5, EL PASO (WESTEX 60)

TEMP., DEG.C

GEO THERMAL GRADIENT
HUECO TANKS #6, EL PASO (WESTEX 61)

TEMP., DEG.C

GEO THERMAL GRADIENT
HUECO TANKS #7, EL PASO (WESTEX49)

TEMP., DEG.C

GEOTHERMAL GRADIENT
HUECO TANKS #8, EL PASO (WESTEX)
TEMP., DEG.C

GEO THERMAL GRADIENT
HUECO TANKS #9, EL PASO (WESTEX)

GEOTHERMAL GRADIENT
HUECO TANKS #10 EL PASO (WESTEX)

TEMP., DEG.C

GEO THERMAL GRADIENT
HUECO TANKS #11 EL PASO (WESTEX)

TEMP., DEG.C

GEO THERMAL GRADIENT HUECO TANKS #12 EL PASO (WESTEX)

TEMP., DEG.C

GEO THERMAL GRADIENT
HUECO TANKS #13, EL PASO

TEMP., DEG.C

GEO THERMAL GRADIENT
HUECO TANKS #14 EL PASO

TEMP., DEG.C

GEO THERMAL GRADIENT
HUECO TANKS #15, EL PASO

TEMP., DEG.C