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EXPLORATION CASE STUDY (through early 1980) OF THE HUECO TANKS GEOTHERMAL AREA, EL PASO COUNTY, TEXAS AND OTERO COUNTY, NEW MEXICO

by

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INTRODUCTION

The Earth Science Laboratory (ESL), in support of the Department of Energy (DOE)/Division of Geothermal Energy's (DGE) User-Coupled Confirmation Drilling Program, has undertaken preparation of a series of exploration case histories for a variety of low- to moderate-temperature geothermal resources, including Hueco Tanks, Texas, the subject of this report. These case histories will aid selection of proposals to DOE/DGE for participation in the User-Coupled Program.

The Hueco Tanks geothermal area, as presently defined, spans the Texas-New Mexico border roughly 20 miles northeast of El Paso, Texas (Figure 1). Studies by Gilliland (1979) have shown that several industries in El Paso as well as the nearby Fort Bliss military reservation could directly and profitably utilize low- to moderate-temperature geothermal energy if developed at Hueco tanks.

Abnormally warm well waters were noted in the Hueco Tanks area by King, King and Knight (1945) on their geologic map of the Hueco Mountains, just east of the resource area (Figure 1). Interest in Hueco Tanks as a potential geothermal resource, however, was initially generated by Hoffer (1979) and colleagues at the University of Texas/El Paso (UTEP) during their Trans-Pecos Texas (Figure 1) geothermal study between 1975 and 1978. Hoffer (1979, p. 13, 14) delineated a ninety square mile thermal anomaly, including the Hueco Tanks site and extending northward into New Mexico, in which shallow well water temperatures reached 71^{o}C and silica geothermometry indicated reservoir temperatures reaching 151^{o}C. Maximum actual and predicted reservoir temperatures occur in New Mexico. Initial interest, however, was directed

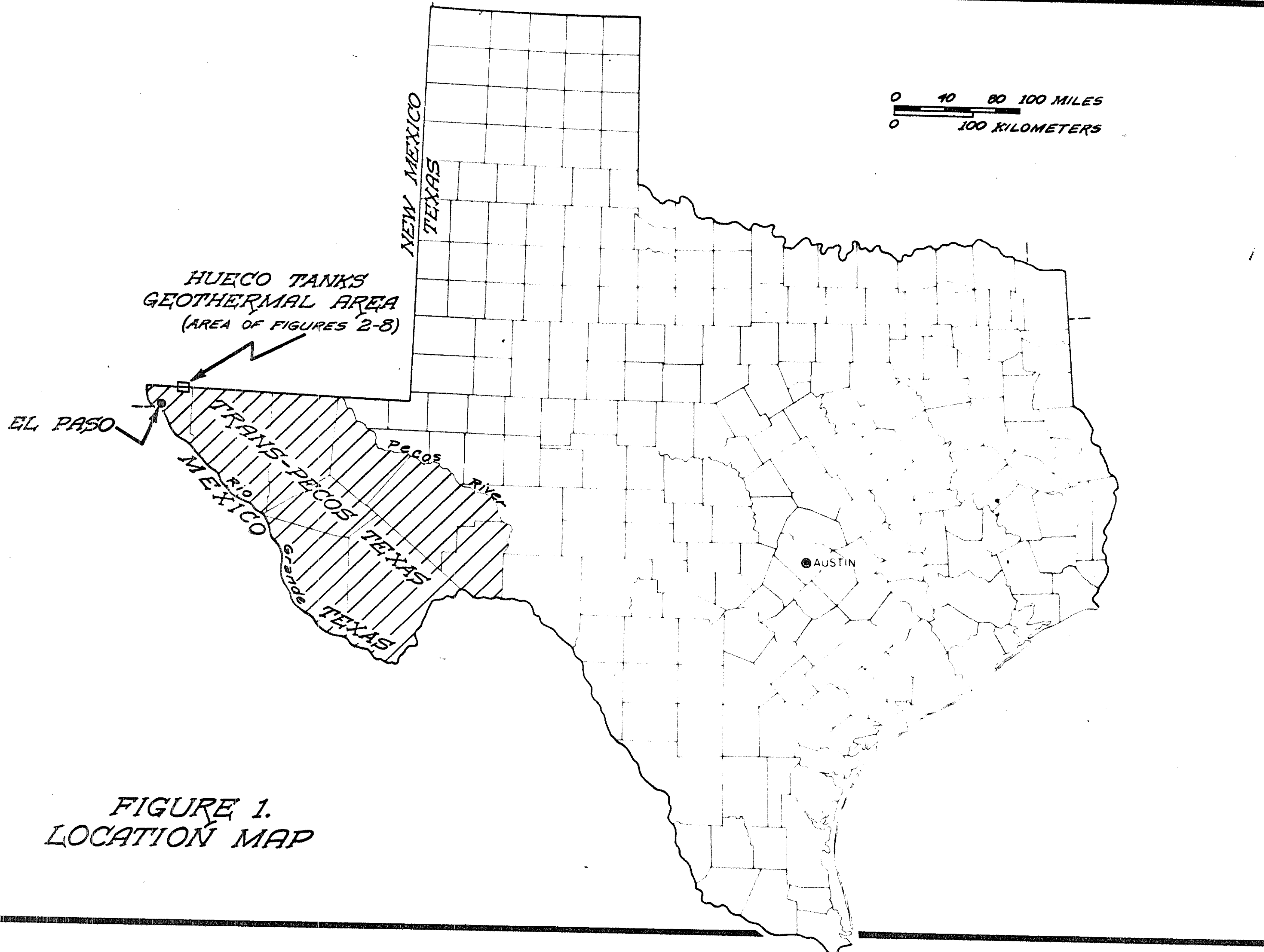


FIGURE 1.
LOCATION MAP

toward the Texas portion of Hoffer's anomaly -- the Hueco Tanks site -- probably because of proximity to El Paso, but perhaps also because of difficulty of access to New Mexico's portion of the Fort Bliss military reservation, which covers much of the anomaly.

A fairly detailed geophysical evaluation of the Hueco Tanks area was undertaken by UTEP, under the sponsorship of the Texas Energy Advisory Council (TEAC) during early and mid-1979. The evaluation comprised gravity, resistivity and microearthquake studies as well as shallow to intermediate depth thermal gradient drilling. Results of the evaluation were encouraging (shallow thermal gradients as high as 310°C/km were discovered) and a similar exploration program was proposed for adjacent New Mexico on the Fort Bliss reservation to the north.

The Fort Bliss-New Mexico extension of the Hueco Tanks exploration program was subsequently approved and funded by DOE/DGE and the Texas Energy and Natural Resources Advisory Council (TENRAC, formerly TEAC) in late September 1979. Shortly thereafter, DOE/DGE recommended that additional geological, geochemical, and hydrologic background data be gathered and interpreted in support of the exploration program. The Texas Bureau of Economic Geology (TBEG)/University of Texas at Austin (UTA) was granted a subcontract to complete this work.

At this writing, UTEP has completed limited gravity, resistivity and microearthquake studies on the Fort Bliss-New Mexico portion of the thermal anomaly and plans to begin thermal gradient drilling in the near future. Results of these surveys have not been published. TBEG has completed background geological, hydrologic and geochemical literature studies as well as a study of temperature; geochemistry and geothermometry of existing wells in the area of interest. Results of this study will soon be summarized by Henry and Gluck (1980).

The purposes of the present paper are: (1) to summarize and discuss results of the individual exploration techniques employed to date at Hueco Tanks; and (2) to examine the overall exploration strategy and sequence devised to evaluate the Hueco Tanks resource and its extension northward into New Mexico.

REGIONAL SETTING

The Hueco Tanks geothermal area is situated in Trans-Pecos Texas (Figure 1) within what Chapin (1971) believes is the southern extension of the Rio Grande rift. The rift, a sub-zone of the Basin-and-Range province near its eastern border with the Great Plains, is characterized by abnormally high heat flow ($\geq$1.8 H.F.U.), which may in turn reflect crustal thinning (Chapin, 1971; Decker and Smithson, 1975; Reiter et al., 1975).

Physiography of Trans-Pecos Texas and adjacent New Mexico is typical of the Basin and Range, being dominated by northwesterly-trending fault block mountains separated by deeply alluviated valleys, or, as they are locally known, bolsons.

Folded Precambrian schists, clastic metasedimentary rocks, carbonates and metarhyolites are the oldest rocks exposed in Trans-Pecos Texas and adjacent Mexico and New Mexico (King and Flawn, 1953). These Precambrian rocks are unconformably overlain by a marine sedimentary sequence of variable thickness and of Cambrian through Permian age dominated by carbonates but locally including clastic sediments. Locally intense deformation and disruption of this sequence provides evidence for the Late Mississippian-Early Permian Ouachita orogeny (King, 1935; Flawn and others, 1961). Pennsylvanian and Permian carbonates in the Hueco tanks region are relatively undeformed.

The Cambrian-Permian sequence is unconformably overlain by a second variable-thickness marine sequence ranging in age from Jurassic (Haenggi, 1966) through early Tertiary, but dominated by Cretaceous limestone and shale. This sequence and subjacent rocks were extensively folded and thrust-faulted during the Late Cretaceous-Early Tertiary Laramide orogeny.

Paleozoic to earliest Cenozoic sedimentary rocks throughout Trans-Pecos Texas and adjacent areas are locally concealed beneath diverse volcanic rocks -- or intruded by their plutonic equivalents -- of Late Eocene through Miocene age. These volcanic rocks comprise basaltic and sodium-rich feldspathoidal rocks, syenites and trachytes, and rhyolites, a distinctive assemblage which Backer (1977) feels may be associated with intracontinental rifting.

Young volcanics (Pleistocene or Recent), possible evidence of shallow hot magma chambers, are unknown in Trans-Pecos Texas. The nearest young volcanics -- basaltic cinder cones, flows and maars -- occur about 30 km (20 miles) west of El Paso (Hoffer, 1979). Thus, the heat source for the region's geothermal phenomena is likely to be deep circulation along faults in an area of abnormally high heat flow, in turn reflecting extension, crustal thinning and perhaps mantle diapirism associated with the Rio Grande rift.

Basin and Range faulting commenced in Trans-Pecos Texas during late Oligocene or Early Miocene (Stevens, 1969) and has continued intermittently to the present. Bolsons (basins) created during this faulting are filled with unconsolidated and semi-consolidated sediments shed from adjacent fault-block ranges. The sediments, which have been partially drill-tested in a deep (4,633 feet) well in Hueco Bolson about 22 miles west of the Hueco Tanks geothermal area, comprise clay, silt, sand, gravel and caliche (Davis and Leggatt, 1967). Thickness of these sediments is estimated to be about 7,000 feet at the drill site and may be as much as 9,000 feet elsewhere in Hueco bolson (Davis and Leggatt, 1967; Gates and Stanley, 1976).

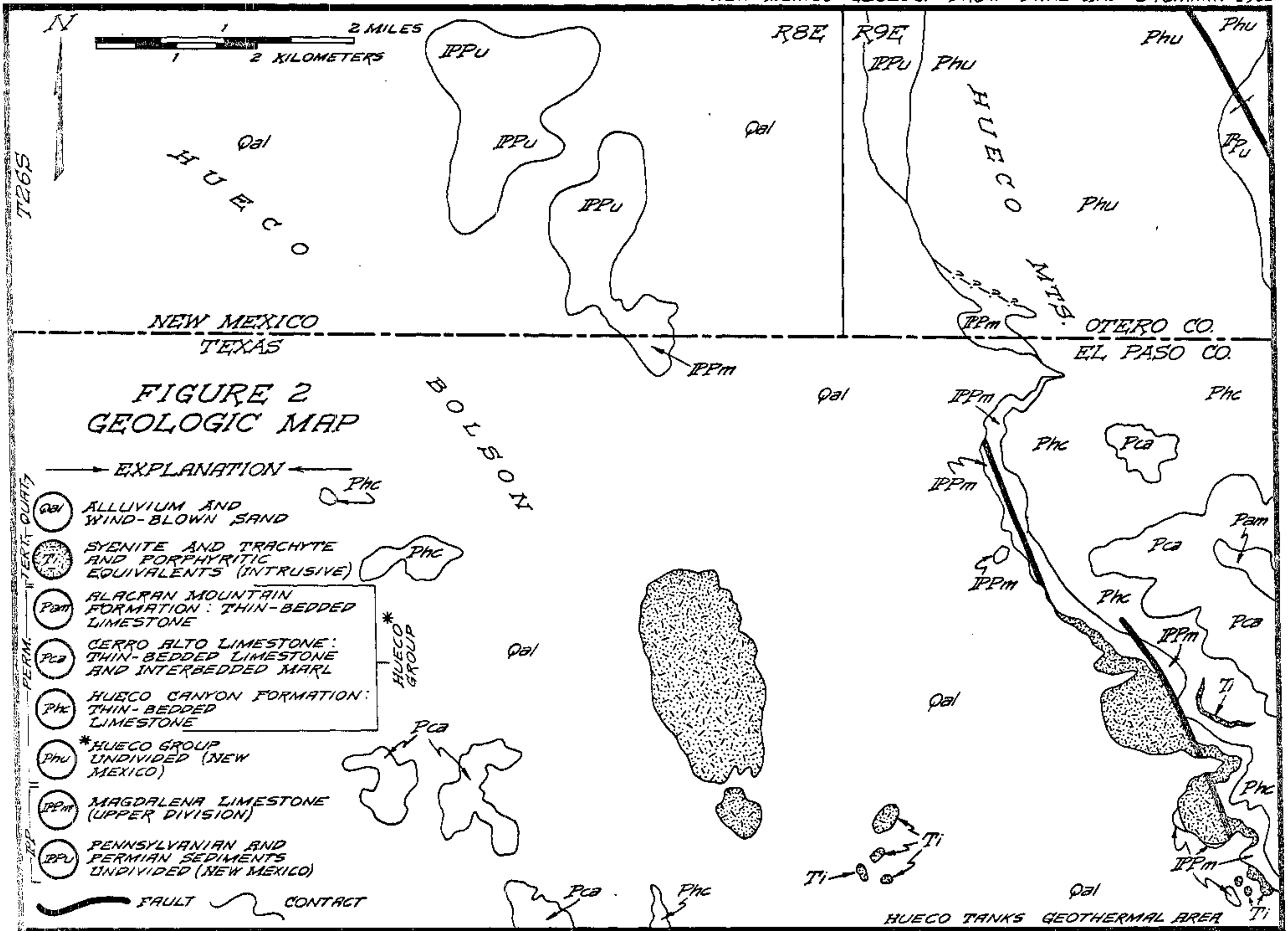
GEOLOGY

As of late 1979, detailed ($\geq$1:24,000) geologic mapping had not been undertaken in support of the Hueco Tanks geothermal project, even though preliminary resistivity, gravity and thermal gradient surveys had been completed (Roy and Taylor, 1979). Such mapping should certainly be completed before more expensive subsurface techniques are applied to evaluation of the resource.

Figure 2 illustrates the geology of the Hueco Tanks area as compiled from three published sources (King and others, 1945; Williams, 1963; and Dane and Bachman, 1965). The Pennsylvanian to Permian Magdalena limestone (equivalent to the undivided Pennsylvanian-Permian sediments in New Mexico) is the oldest unit exposed within the map area. It is overlain, in conformable sequence, by the three limestones of the Permian Hueco Group: the Hueco Canyon, Cerro Alto and Alacran Mountain Formations. These units are intruded by plugs, dikes and sills of trachyte and syenite (and porphyritic equivalents) of mid-Tertiary age (Henry and Gluck, 1980).

The geothermal area is situated along the eastern margin of the Hueco

NEW MEXICO GEOLOGY FROM DANE AND BACHMAN 1965



TEXAS GEOLOGY FROM KING, KING AND KNIGHT (1945) AND WILLIAMS (1963)

Bolson, a broad asymmetric graben bordered on the east by the Hueco Mountains (Figure 2). The deepest portion of the Hueco Bolson is adjacent to the Franklin Mountains, roughly 22 miles west of the geothermal area, where depth to bedrock may be as much as 7,000 feet (Davis and Leggat, 1967). Bolson-fill, however, is quite shallow in the geothermal area (as could be predicted from the presence of scattered small limestone and syenite-trachyte outliers) where two shallow thermal gradient holes, discussed in a subsequent section, penetrated limestone bedrock (Roy and Taylor, 1979).

The Hueco Tanks area as mapped to date is structurally uncomplicated. The Paleozoic carbonates are flat-lying to gently folded and tilted and were apparently passively intruded by the syenite-trachyte plutons with no structural disruption. Only two faults are mapped within the area of Figure 2, but this probably reflects the map scale rather than structural reality. The two mapped faults, of normal displacement, occur along the boundary between the Hueco Bolson and Hueco Mountains. It is very likely that similar faults underlie the shallow alluvial cover of the geothermal area in the eastern Hueco Bolson, and that these faults may control deep and rapid circulation and heating of geothermal waters (Henry and Gluck, 1980). This possibility could be usefully investigated through detailed geologic mapping of the resource area.

No mineral deposits or hydrothermal alteration have been documented in the Hueco Tanks area, although examples of these phenomena might be discovered by further detailed mapping. Surface thermal manifestations are thus far confined to the "hot" wells shown on King, King and Knight's (1945) geologic map and discussed in Hoffer (1979). Hot Springs, sinter and associated alteration have not been reported, but may have been overlooked.

WELL WATER CHEMISTRY AND GEOTHERMOMETRY

The major thermal anomalies which include the Hueco Tanks site were delineated by Hoffer (1979) through measurement of well water temperatures and application of silica geothermometry. At $\geq 30^{\circ}C$ (roughly $7^{\circ}C$ above regional average), the well water temperature anomaly, elongate north-northwest, covers about 75 square miles in southern New Mexico and northeastern El Paso County, Texas. Highest actual water temperatures (up to $71^{\circ}C$) occur in New Mexico: Hueco Tanks actually represents only a small portion of the potential resource. Figure 3 shows the position of Hoffer's well water temperature anomaly relative to a shallow thermal gradient anomaly subsequently outlined by drilling and discussed in the following section. Figure 4 shows this same thermal gradient anomaly relative to Hoffer's (1979) silica geothermometer anomaly. Data points on which Hoffer's anomalies are based are not given, but must include the "hot" well shown on King and others (1945) geologic map and included on Figures 3 and 4.

Hoffer's (1979) well water silica geothermometry was apparently based on quartz equilibrium, yielding reservoir temperatures as high as $151^{\circ}C$ in southern New Mexico north of Hueco Tanks. Subsequent work by The Texas Bureau of Economic Geology (Henry and Gluck, 1980) indicates that chalcedony

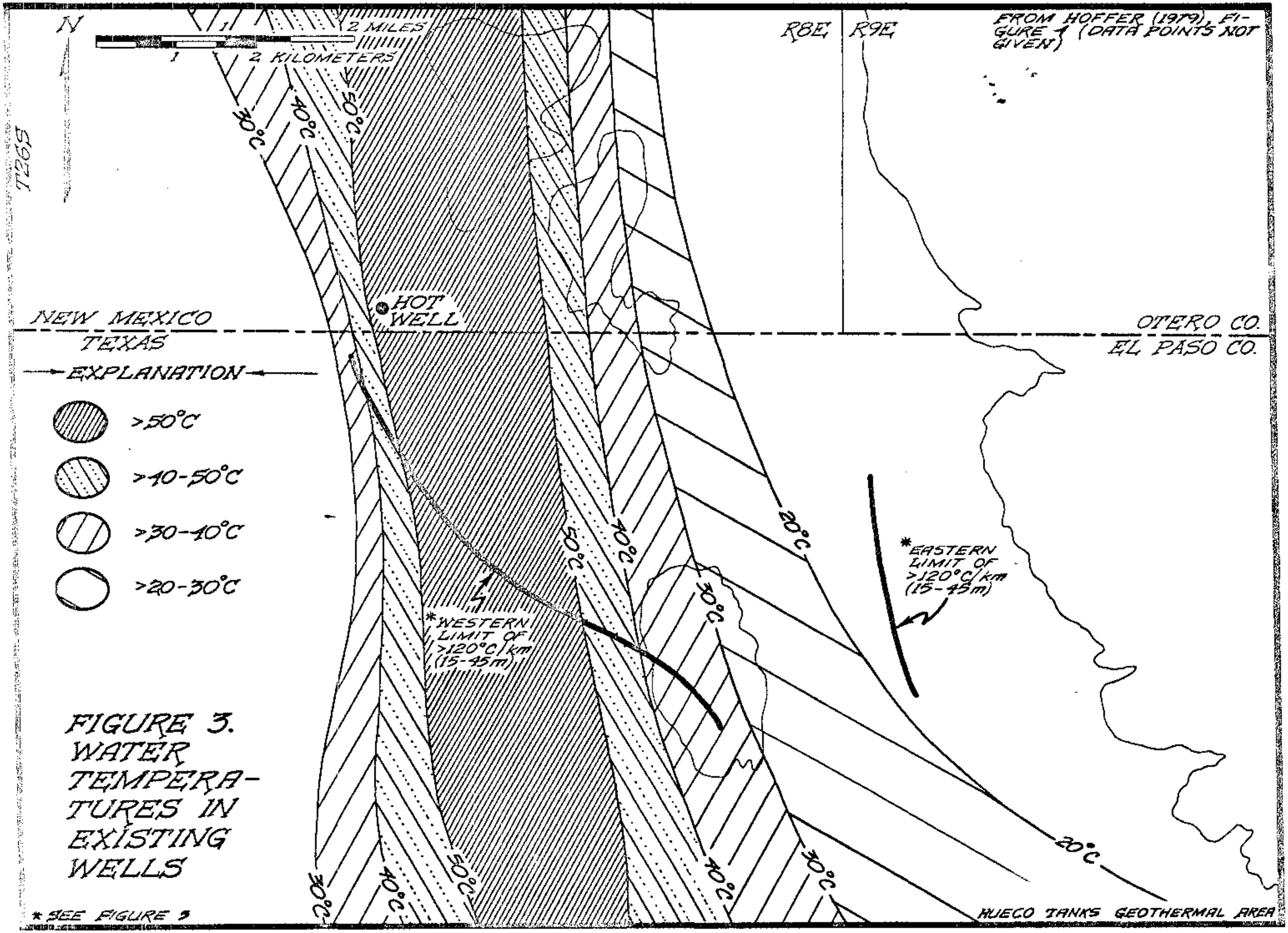


FIGURE 3. WATER TEMPERATURES IN EXISTING WELLS

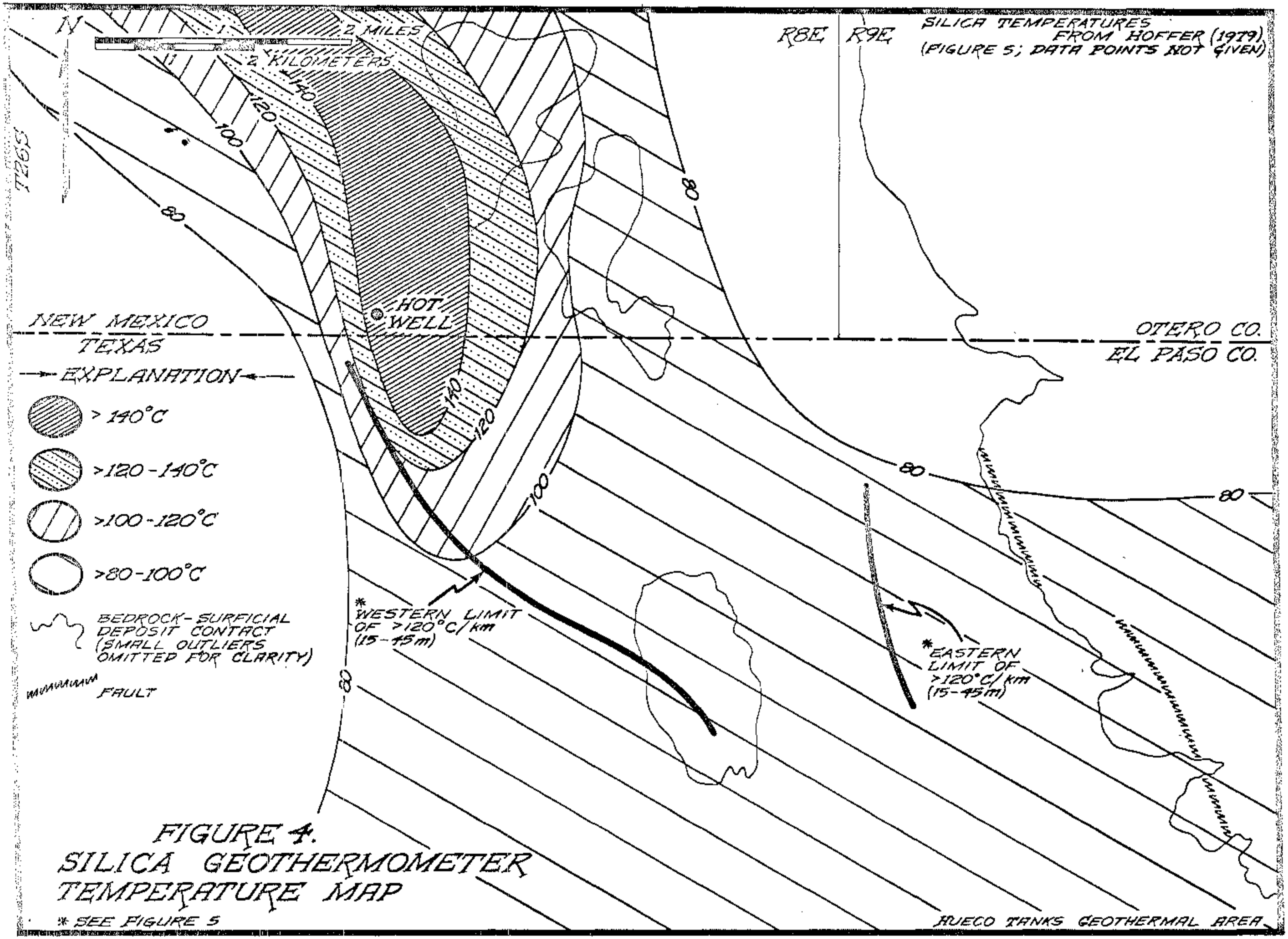


FIGURE 4.
SILICA GEOTHERMOMETER TEMPERATURE MAP

* SEE FIGURE 5

equilibrium is more likely, and that reservoir temperatures will probably not exceed 80°C.

THERMAL GRADIENT DRILLING

Twelve shallow (45-50 m) and three intermediate depth (120-300 m) thermal gradient holes were completed at Hueco Tanks by UTEP in 1979 (Roy and Taylor, 1979). Results of this drilling program are shown on figures 5 and 6. Figure 5 is a contour map of shallow gradients measured between 15 m and 45 m (to avoid confusing near surface perturbations). A strong anomaly, open to the north, is immediately apparent just north of the largest syenite-trachyte outlier. Gradients within this anomaly, all within bolson-fill, reach 310°C/km. Figure 6 illustrates intermediate-level gradients, including those in two holes (120 m and 300 m total depths) which penetrated bedrock. These deeper gradients are still high, although less so than those measured nearer to the surface. Somewhat discouraging is a rapid decrease in gradient (to 67°C/km) in the lower 30 m of the deepest [300 m] hole).

RESISTIVITY STUDIES

Two Schlumberger resistivity soundings were completed in the area of the shallow thermal gradient drill hole array in 1979 (Roy and Taylor, 1979). Survey instrumentation details are not published. Modeled results of the two soundings, the locations of which are shown on Figure 7, indicate a thin, resistive overburden above 400-500 meters of 8-9 ohm-meter material, in turn above a second highly resistive zone. Additional resistivity studies in 1980 on the Fort Bliss military reservation north of Hueco Tanks yielded

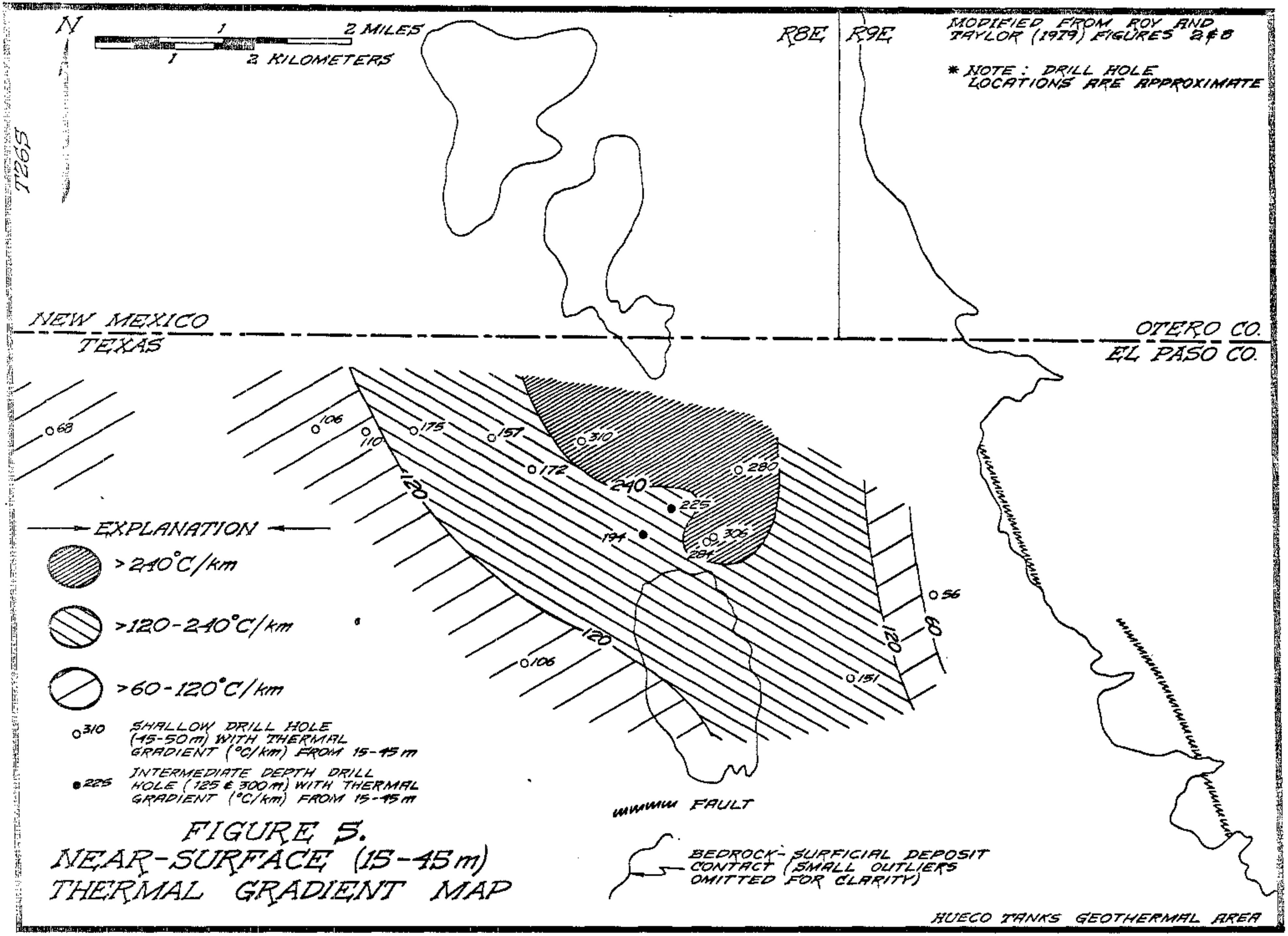


FIGURE 5.
NEAR-SURFACE (15-45 m) THERMAL GRADIENT MAP

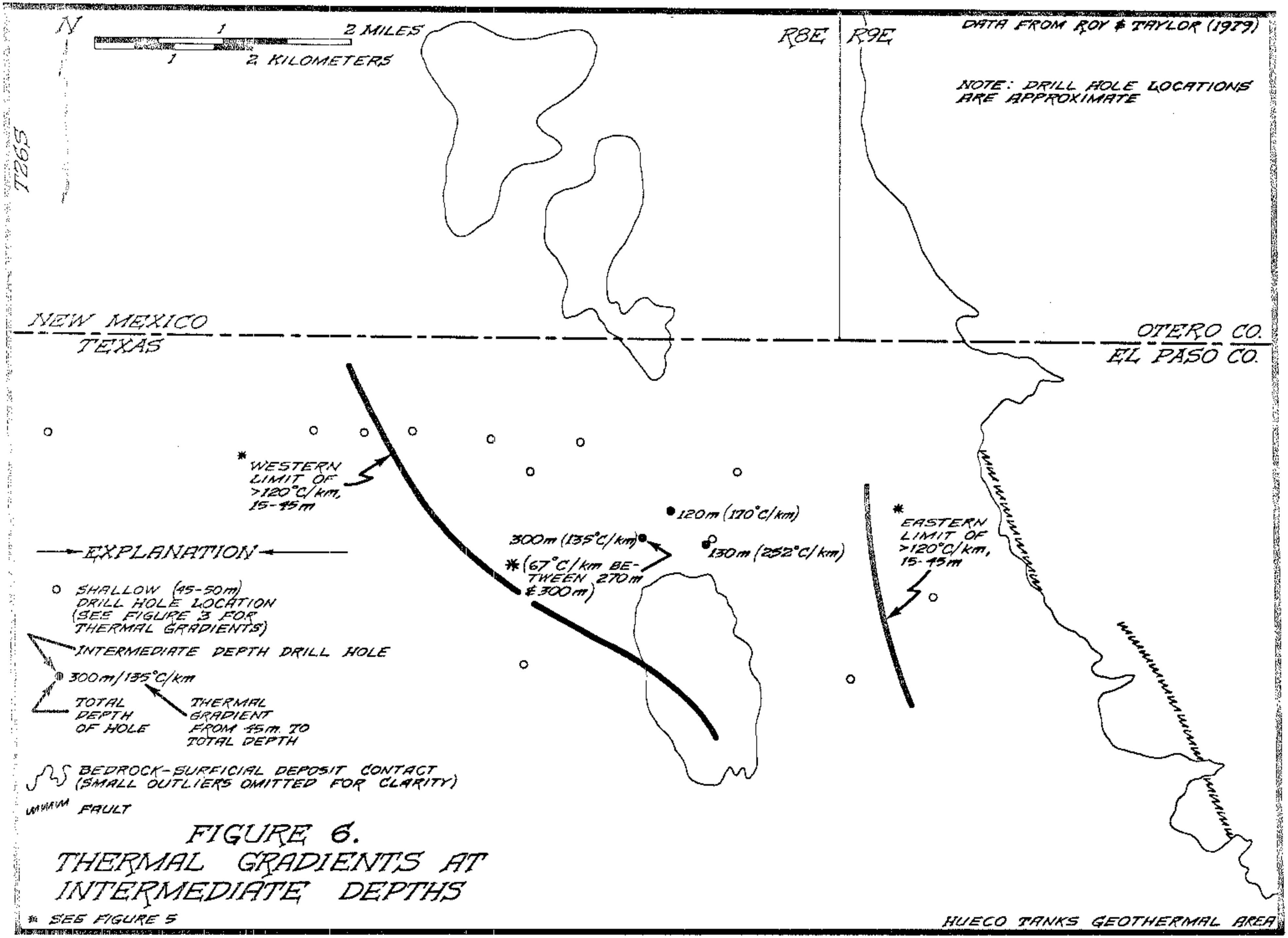


FIGURE 6.
THERMAL GRADIENTS AT INTERMEDIATE DEPTHS

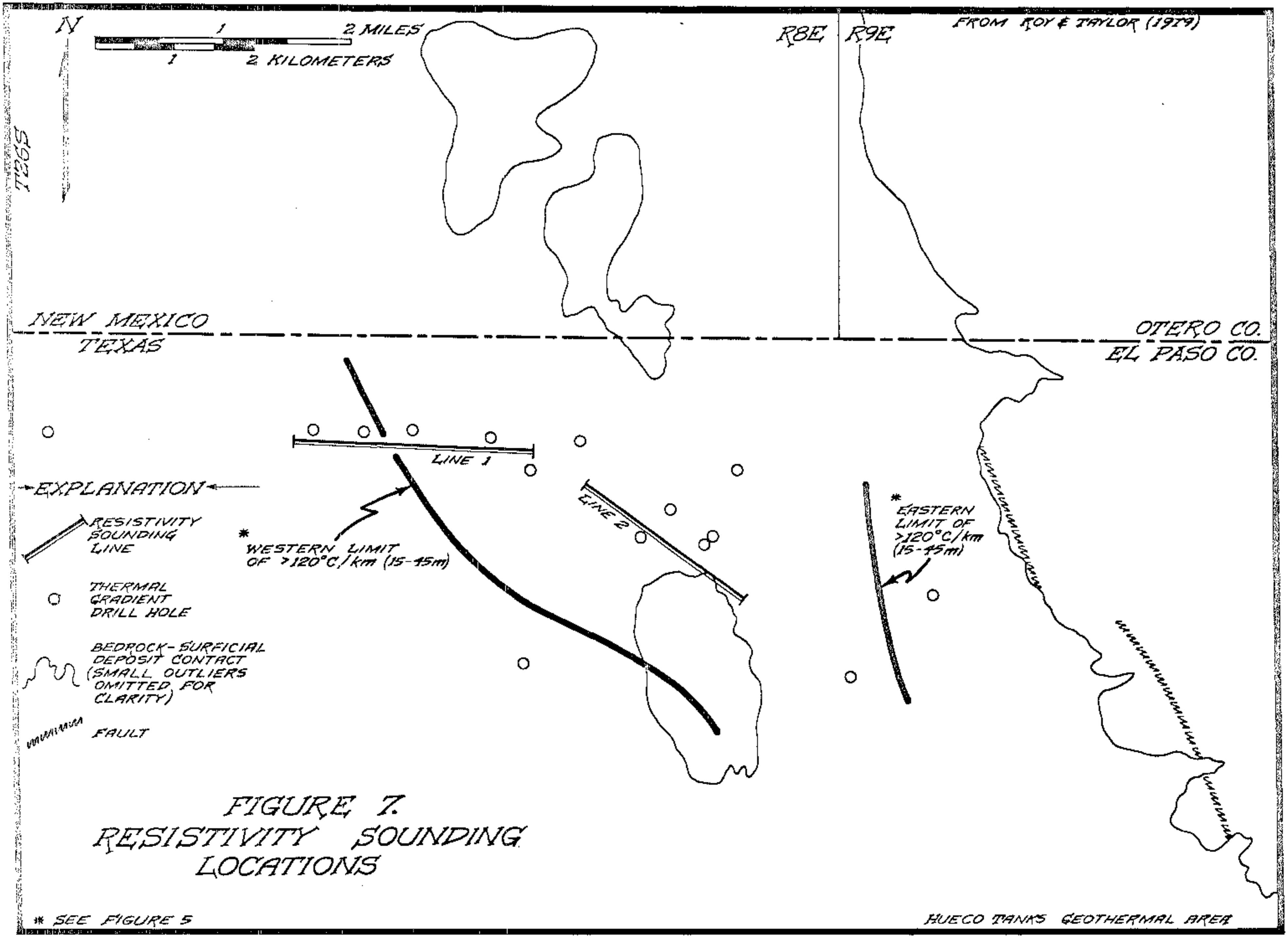


FIGURE 7.
RESISTIVITY SOUNDING LOCATIONS

measurements at depth as low as 0.3 ohm-meters (White, 1980).

The resistivity results should be interpreted with some caution. A deep test well in the western Hueco Bolson about 22 miles west of Hueco Tanks penetrated numerous potentially conductive clay horizons and encountered highly conductive waters with up to 42,000 ppm total dissolved solids (Davis and Leggatt, 1967). Such clay horizons and conductive waters could easily be present beneath the Hueco Tanks area.

GRAVITY STUDIES

A detailed gravity survey of the Texas portion of the Hueco Tanks resource was completed by UTEP in conjunction with their drilling and resistivity studies. Results of the gravity survey are illustrated on figure 8. Lowest values occur at the western edge of the survey and correspond to a westward increase in thickness of low-density bolson fill (alluvium). Continuation of this trend is readily apparent on Davis and Leggat's (1967) Bouguer anomaly map of the Hueco Bolson. Other lows on the Hueco Tanks gravity map may likewise reflect depth of alluvium. Roy and Taylor (1979) feel that the northwest-southeast trending low in the north-central portion of the survey area may represent a fault (or fault zone) along which hot waters are probably rising from depth. Speculation on the likelihood of such a fault would certainly benefit from detailed surface mapping.

A second gravity survey was completed on the New Mexico portion of the thermal anomaly by UTEP early in 1980. Exact location and results of the survey are unavailable at this writing, but UTEP feels the gravity data may indicate, as at Hueco Tanks, the concealed presence of faults or fault zones

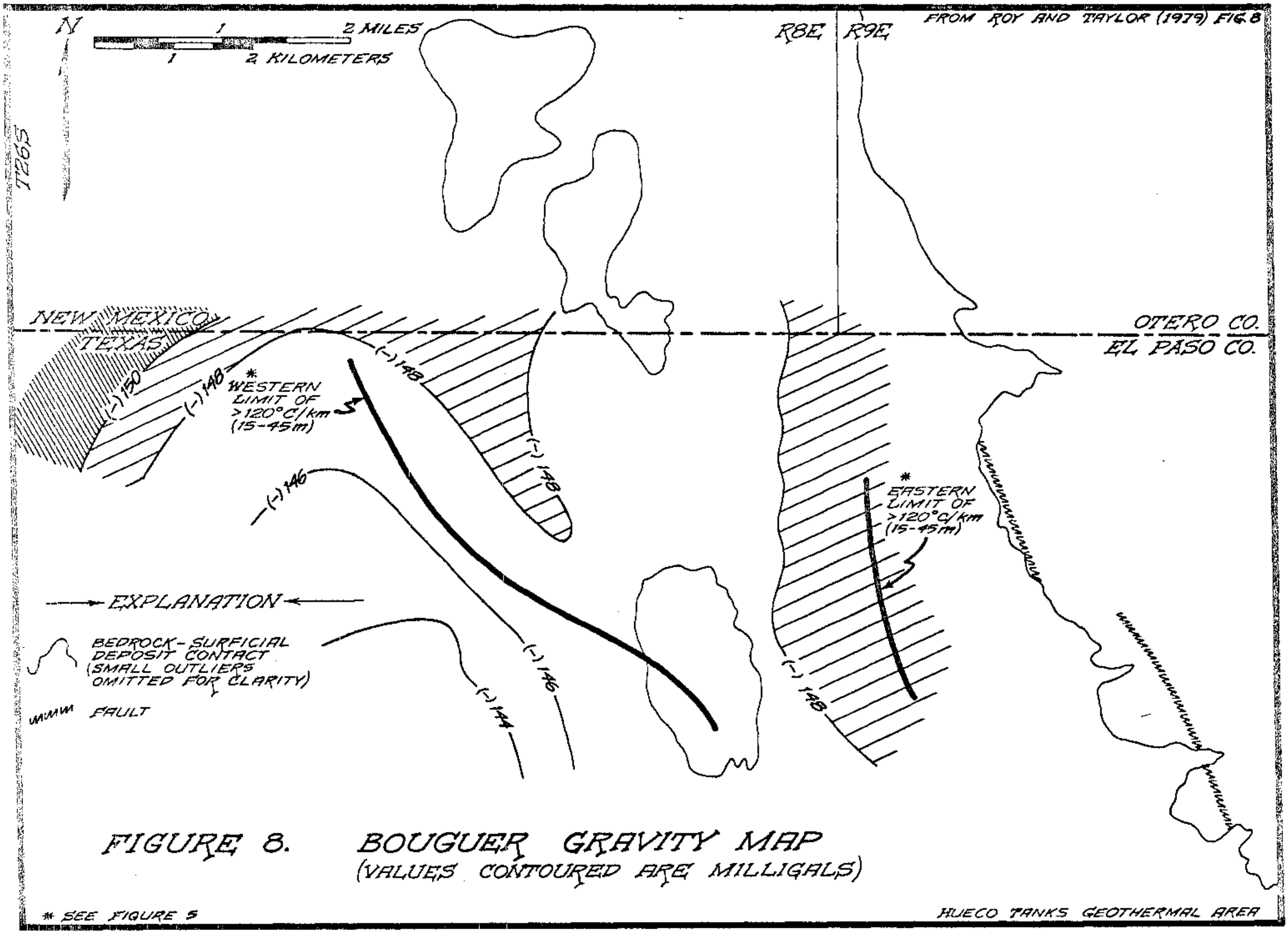


FIGURE 8. BOUGUER GRAVITY MAP
(VALUES CONTOURED ARE MILLIGALS)

controlling thermal fluid flow (White, 1980).

MICROEARTHQUAKE STUDIES

One-week microearthquake studies were completed at Hueco Tanks in 1979 (Roy and Taylor, 1979) and in adjacent New Mexico in early 1980 (White, 1980). The Hueco Tanks survey utilized triangular arrays of Sprengnether MEQ-800 microearthquake recorders. Instrumentation details for the nearby New Mexico survey have not been published. Neither survey detected natural seismic events, but this could (at least at Hueco Tanks) reflect brevity of the recording period.

DISCUSSION

The Hueco Tanks geothermal area, as previously noted, represents only a small portion of the major well water and silica geothermometer temperature anomaly delineated by Hoffer (1979). The larger portion of the anomaly, with the highest actual and predicted temperatures, actually occurs in New Mexico. Nonetheless, UTEP's original investigation of the anomaly was confined to Texas -- the Hueco Tanks site. Only after a fairly detailed evaluation at Hueco Tanks was exploration proposed for the New Mexico portion of the anomaly.

Since the most encouraging portion of the thermal anomaly occurs in New Mexico, reasons for beginning its evaluation in Texas are unclear. They may include: (1) proximity of the Hueco Tanks site to El Paso and thus to a concentration of potential users of the resource; and (2) difficulty of access to the New Mexico portion of the anomaly, much of which is covered by the Fort

Bliss military reservation.

The Hueco Tanks geothermal area and its northern extension into New Mexico definitely should be mapped at a scale of 1:24,000 or more. Such mapping can yield valuable information on various reservoir parameters (particularly structural) at relatively low cost. The geological literature study recently completed by TBEG should provide useful background for the geologic mapping.

The heat source for warm well waters in the Hueco Tanks geothermal area and its New Mexico extension, as well as for high thermal gradients at Hueco Tanks, is almost certainly deep circulation along faults (and perhaps in cavernous limestones) in an area of abnormally high regional heat flow. This supposition is based on the probable location of the thermal anomaly within the Rio Grande rift, with known anomalous heat flow, and on the absence of young volcanics within or near the thermal anomaly. Thus, accurate delineation of structural control will be very important in characterization of the resource, and the need for good geologic mapping is again emphasized. Subsurface structures may be postulated through projection from outcrop, through gravity and resistivity studies (already employed by UTEP) and perhaps by seismic techniques, although the latter are too expensive for general geothermal reconnaissance. Resistivity methods in the Hueco Tanks area and vicinity should be used with caution because of the known presence in valley-fill sediments of conductive clay horizons and saline waters.

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