# PRELIMINARY GEOTHERMAL ASSESSMENT OF THE HYDER AREA

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This report is preliminary and has not been edited
or reviewed for conformity with Arizona Geological Survey standards

# I. INTRODUCTORY MATERIAL

## A. Location and Access

The Hyder area consists of the Palomas Plain, Hyder Valley, and the northern portion of the Sentinel Plain, Part of the area is in western Maricopa County and the remainder is in Yuma County (Figure I-1). The Gila River corsses the south-central portion of the area in an east to west direction on its way to the Colorado River. Highway 80 parallels the river to connect the agriculture communities of Gila Bend and Yuma. Highway 80 is also the major route to southern California. Secondary dirt roads provide access to the numerous farms in the southern portion of the Palomas Plain and Hyder Valley.

## B. Local Support

Numerous contacts were established with the owners and operators of the farms in the area. They provided access to their wells and expressed enthusiasm in the goals for this project. Special recogniation goes to Nick Kondora of Whitewing Ranch and Paul Manera, P.E., for their time and interest.

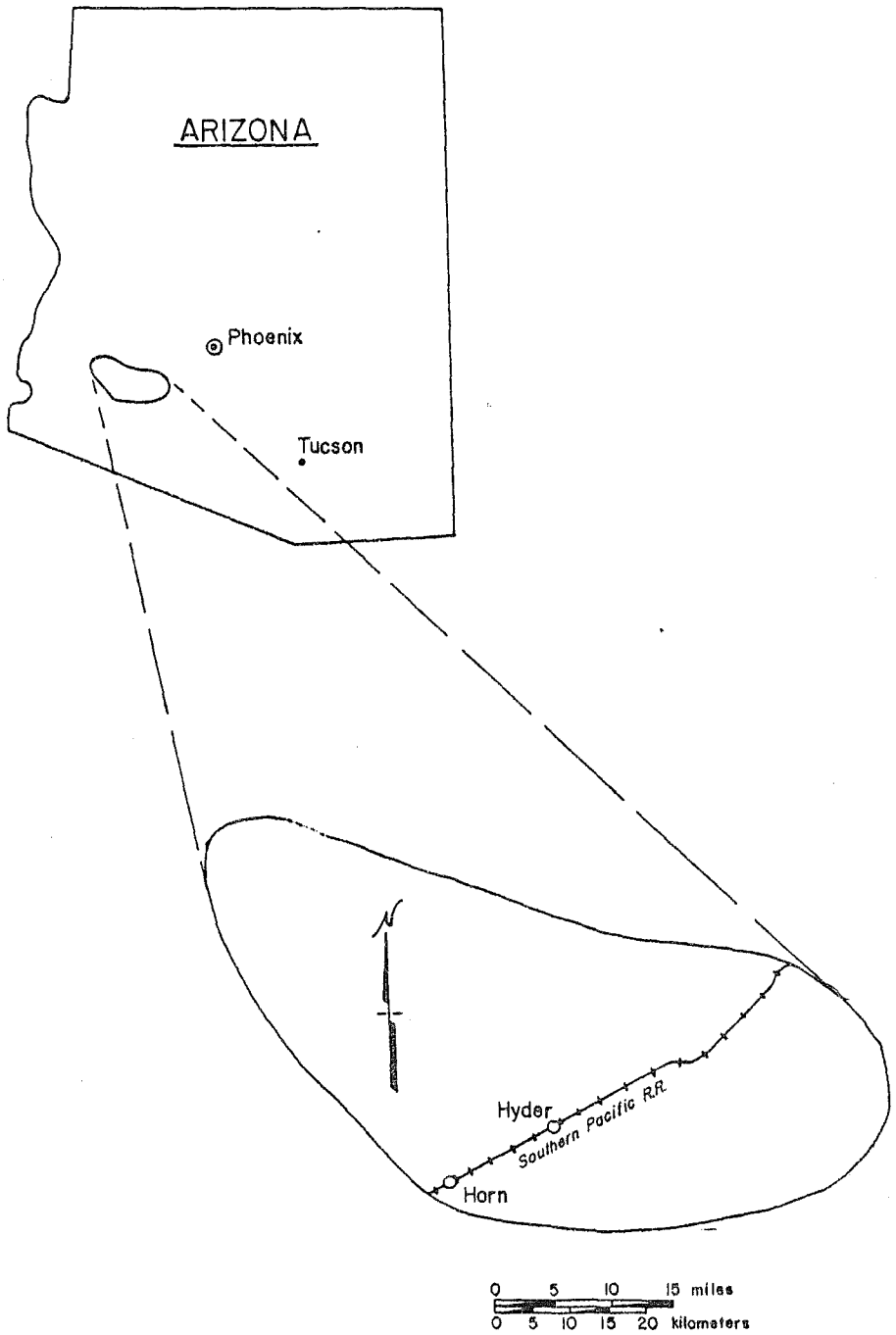


FIGURE I-1. Location of the Hyder Study Area, Arizona.

## II. SUMMARY AND RECOMMENDATIONS

### A. Development of Potential Resources

The water balance of the area was evaluated by examining the water in storage and the potential for recharge. Annual precipitation is approximately 6 inches (13.8cm) per year. Much of this water is returned to the atmosphere through evapotraspiration.

Total volume of water velow 300m is 60,600 $hm^3$. Recoverable water below the same datum is set at 23,500 $hm^3$. Water from existing wells generally contain less than 5,000 mg/l dissolved solids. No known wells contain more than 10 mg/l fluoride. The dissolved solids and salt content of a hydrothermal reservoir would no doubt contain higher values, but probable well not exceed 20,000 mg/l.

Using a normal temperature gradient of 35°C/km for the basin, a temperature of 150°C would be achieved at about 3.5 kilometers. Abnormal temperature gradients north of Baragan Mountain, south of Horn, and south of Turtleback Mountain suggest 150°C temperatures could be achieved at depths of less than 2.5 kilometers. Substantiation of these projected temperatures should be undertaken as a first step in the development of this area.

## III. LAND STATUS

The Hyder Valley - Palomas Plaon study area encompasses nearly 1,200 $km^2$ of basin material. The total watershed is about 2,800 $km^2$ (Map III-1). Table III-1 is a breakdown of the land situation by major land holders.

Table III-1 Land Status of Hyder Valley - Palomas Plain

| Owner or Trust Group | Area ($mi^2$) | Area ($km^2$) |
|---|---|---|
| Private Ownership | 118. | 305.5 |
| State of Arizona Trust | 142.9 | 370.1 |
| BLM Resource Lands | 587.3 | 1521.1 |
| Military Proving Grounds | 216. | 559.4 |
| Kofa Game Range | 22 | 57 |
| TOTAL | 1086.2 | 2812.1 |

Approximately 54% of the land is under BLM juristiction, 13% is State land and 11% is privately owned. The remaining is held by the military or is in the Kofa Game Range.

## IV. RESOURCE EVALUATION

### A. Introduction

A review of existing geological, hydrological and temperature data from the Dateland-Hyder area was undertaken. This was judged to be the first step in assessing the area's geothermal potential. Additional information was gathered from firsthand field observations and discussions with the local population.

Temperature measurements and chemical geothermometry suggest three areas where 40° to 100°C waters may be found at depths of 500 to 1,000 meters. Projection of thermal gradients indicate 200°C temperatures may be encountered at depths as shallow as 2,000 meters. Such a projection assumes continuation of the most favorable thermal gradients. Additional site-specific work will be required to delineate these more favorable areas.

### B. Previous Work

Geological and hydrological studies on parts of the area or adjacent areas include those of Ross (1922, 1923), Bryan (1925), Wilson, (1933), Armstrong and Yost (1958), Ibrahim (1962), and Weist, Jr., (1965). Unpublished hydrology or water-supply reports on areas within the region include those of Babcock, Brown and Heim (1947), Babcock and Kendall (1948), Halpenny and others (1952), Johnson and Cahill (1954), and Cahill and Wolcott (1955). Regional gravity and aeromagnetic studies have been conducted by Peterson (1968), Sauck and Sumner (1970), and Aiken (1975). Water chemistry from selected

wells came from Smith and others (1963), the U.S. Geological Survey Water Resources Open-Files (WATSTORE 1978) and those collected during this study.

## C. Geology

The geologic units of the Hyder-Dateland area can be divided into the bedrock mountain blocks and the basin-fill sediments. Although much of the water will be contained within the basin sediments, it is important to recognize the variey of rock types and ages represented in the bedrock mountain blocks.

1. Bedrock and Mountain Blocks. Precambrian schist, gneiss and granite is exposed in portions of the Tank and Palomas Mountains as well as in the Aztec Hills (Map IV-1). Wilson (1960) placed a Mesozoic date on many of these units, but isotopic dating indicates a much older date of emplacement. Table IV-1 is a listing of important age dates of volcanic units located in or immediately adjacent to the Hyder study area. The genissic granite from the Exxon State well (14)-1 shows a Mesozoic recrystallization date of a Precambrian granite. Extrusive volcanics in the Hyder area are Cenozoic in age with the youngest being Pliocene.

All Precambrian exposures have been extensively fractured and faulted. Quartz-dominated pegmatite dikes and veins may be found throughout these older units, but none were observed in the younger volcanics.

Table IV-1. Radiometric Ages of Rock Samples in the Hyder Area, Maricopa and Yuma Counties, Arizona

| Rock Type or Formation | Location | Apparent Age (m.y.) | Radiometric Age Method, Mineral Dated | Reference, Sample, Any Comments |
|---|---|---|---|---|
| Rhyodacite | lat33°35'10"N, long114°02'35"W | 19.1±0.6 | K-Ar, hornblende | Miller & McKee (1971) |
| | | 20.2±0.6 | K-Ar, biotite | |
| Basalt | lat33°01'03"N, long112°,59'58"W | 18±7.2 | K-Ar, whole rock | Eberly & Stanley (1978) |
| Rhyolitic Tuff | lat33°16'23"N, long113°26'51"W | 23±1.6 | K-Ar, biotit | Eberly & Stanley (1978) |
| Basaltic Andesite | lat33°11'40"N, long112°48'15"W | 19.6±0.4 | K-Ar, whole rock | Shoustra et al. (1976) |
| Basaltic Andesite | lat33°20'24"N, long112°47'40"W | 19.4±0.4 | K-Ar, whole rock | Shoustra et al. (1976) |
| Basaltic Andesite | lat33°25'42"N, long112°52'30"W | 19.1±0.7 | K-Ar, whole rock | Shoustra et al. (1976) |
| Andesite | lat33°25'37"N, long112°57' W | 19.1±0.4 | K-Ar, whole rock | Shoustra et al. (1976) |
| Basaltic Andesite | lat33°23'20"N, long112°49'48"W | 17.7±0.06 | K-Ar, whole rock | Shoustra et al. (1976) |
| Leucocratic Rhyolite | lat33°08'11"N, long113°23'52"W | 18.5±1.5 | K-Ar, whole rock | Eberly & Stanley (1978 |
| Basalt | lat33°06'59"N, long113°33'51"W | 29.3±3.1 | K-Ar, whole rock | Eberly & Stanley (1978) |
| Basalt | lat32°56'06"N, long113°18'05"W | 3.0 ± 0.9 | K-Ar, whole rock | Eberly & Stanley (1978) |
| Basalt | lat32°33'03"N, long112°52'43"W | 21 ± 1.2 | K-Ar, whole rock | Eberly & Stanley (1978) |
| Rhyolitic Tuff | lat32°47'17"N, long114°06'19"W | 23 ± 2.7 | K-Ar, whole rock | Eberly & Stanley (1978) |
| Andesite | T3S, R11W, Sec. 25db | 20.5±1.0 | K-Ar, whole rock | Eberly & Stanley (1978); Andesite from Exxon State Well |
| Gneissic Granite | | 163.7±4.0 | K-Ar, whole rock | (14)-1, 299-235 m; gneissic granite, 771-777m, younger date represents recrystalization in Jurassic time. |
| | | 1080 | Rb-Sr, whole rock | |

2. Basin Sediments. The basin-fill sediments in the Hyder area are similar to those in other basins in southern Arizona. There are mixtures of fine to medium-grained clastics, coarser sands and conglomerates. All sediments are believed to have been deposited since late Cretaceous-early Tertiary time (Eberly and Stanley, 1978; Scarborough and Peirce, 1978).

The sediments are subdivided into an older Unit I and a younger Unit II as proposed by Eberly and Stanley (1978) with the boundary marked by one or more of the following conditions: 1) the first volcanic tuff or basalt flow of mid-Miocene age (13 m.y.); 2) a wide-spread unconformity surface associated with mid-Miocene block-faulting; 3) thick conglomerate sequences associated with this period of block-faulting; 4) the change from unconsolidated to indurated sediments and 5) tilting of the materials that comprise Unit I. Figure IV-1 illustrates this two-fold classification.

Unit I rests directly on a major unconformity which separates the Tertiary sediments, volcanics and reworked volcanic detiritus from the pre-Tertiary bedrock. Unit I includes all basin-fill rocks deposited following the Laramide orogeny, approximately 53 m.y. ago, and the time of the first significant movements following the mid-Miocene volcanic episode of about 18-20 m.y. ago (see Table IV-1). The basal section is generally arkosic with interbedded fanglomerates. Hematite often stains these sediments a distinctive reddish-brown. Deeper portions of the basin may contain several

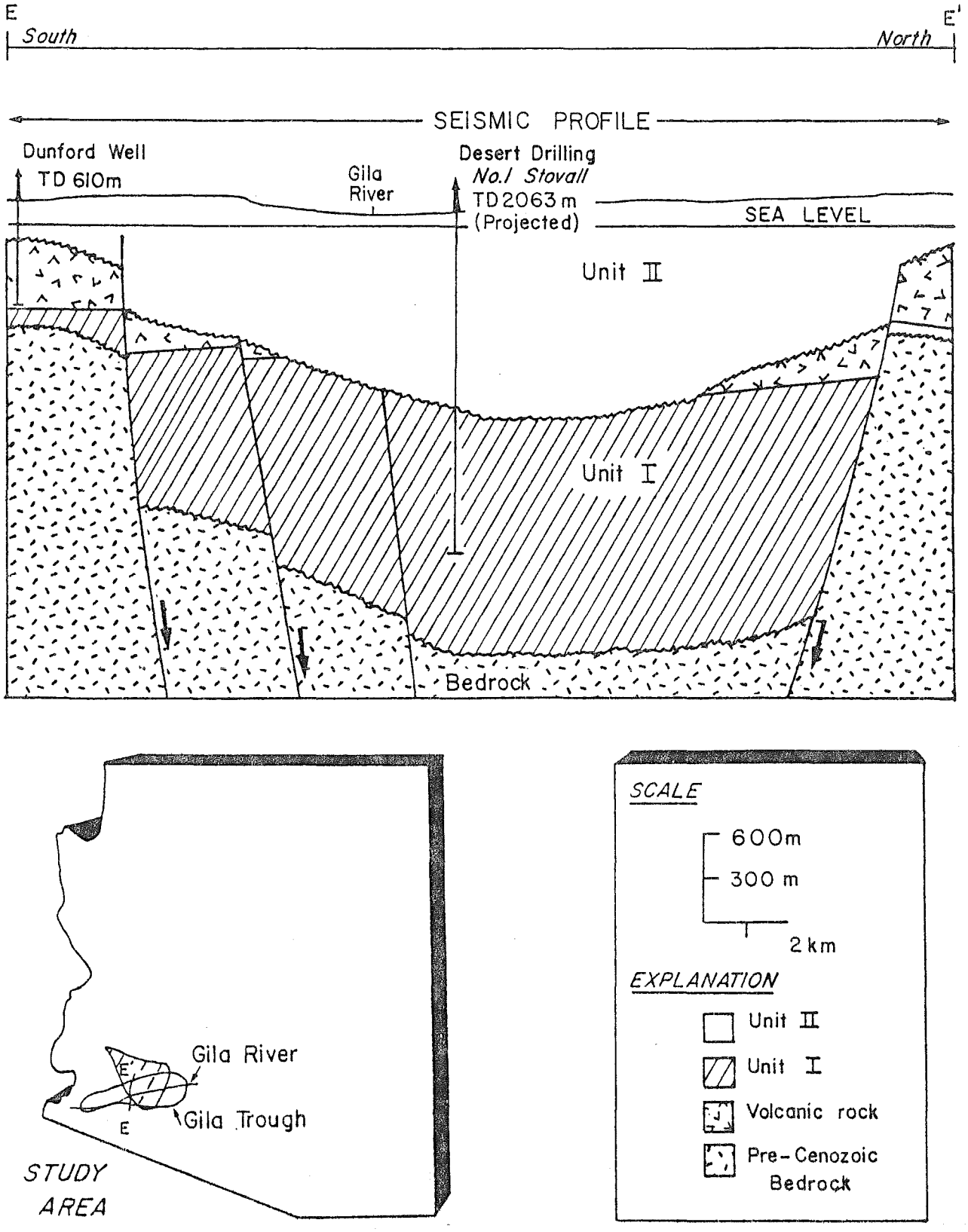


FIGURE IV-1: LOCATION MAP AND CROSS SECTION ACROSS THE GILA TROUGH (FROM EBERLY AND STANLEY, 1978).

hundred meters of this coarse clastic material.

Immediately overlying the basal section is a mixture of mid-Tertiary tuffs, breccias, volcanic flows, reworked volcanic detritus, mudstones and gravels. Numerous unconformities in this section are attributed to the early-Miocene volcanic events and the interim basin and range readjustments. Unit I may be capped by basalt flows. Estimated thickness of Unit I is about 1,400 meters (see Figure IV-1).

Unit I is characterized by interbedded continental sand, gravel, silt and clay. Typically this section is unconsolidated, although the lower portions may contain some calcite or hematite comenting. Evaporites have not been reported in the literature, but high sulfate content from selected wells suggest their presence (Armstrong and Yost, 1958; Weist, 1965).

Figure IV-1 is a structural cross section across a portion of the Gila trough in the Hyder area developed by Eberly and Stanley (1978) from seismic profiles and deep oil test drilling. This seismic profile, constructed by Exxon, demonstrates the graben structure. The thickness of continental sediments is estimated at approximately 2,700 meters.

3. Water Chemistry. Maps IV-2 and IV-3 shows the distribution of fluoride and total dissolved solids, respectively, from wells in the Hyder area. Most wells contain more than 2 mg/l fluoride and about one-third of those sampled contain more than 5 mg/l. No well is currently known to contain more than 10 mg/l fluoride. Recommended limits on fluoride in

drinking water for this area is 1 mg/l or less, Table IV-2 (Hem, 1970). The higher concentrations of fluoride generally occur east of the line between Baragan Mountain and the Agua Caliente Mountains. No obvious variance in concentration can be seen along the axis of the Gila River.

Most wells within the area contain between 500 and 5,000 mg/l dissolved solids. The few wells which exceed 5,000 mg/l are located near the Gila River. Less than 10 percent of the wells contain less than 500 mg/l. The quantity of dissolved solids in the groundwater decreases away from the Gila River.

Chemical data for the water wells on the Whitewing ranch were provided by its manager, Mr. Nick Kondora. No appreciable change in overall water quality was noted between his 1974 values and those obtained during this survey. Except for $HCO_3$, all 1974 values were within expected analytical error. Table IV-3 is a comparison of common ions from the 1974 and 1979 water chemistries. Fluoride, potassium, boron and silica were not evaluated in 1974 and nitrate was not included in the 1979 analyses. The presence of gypsum and halite in the basin is suspected because of the quantity of $SO_4$, Cl, Na and Ca in the water. Low values for $HCO_3$ and Mg suggest low concentrations of calcite and dolomite in those portions of the section that have had recent ground-water movement.

4. Geophysics. State-wide aeromagnetic and gravity maps for Arizona have been compiled by the College of Geosciences, University of Arizona (Sauck and Sumner, 1970; Aiken, 1975).

Table IV-2. Recommended limits of fluoride concentration in drinking water (after Hem, 1970).

| Annual average of maximum daily air temperatures (°F) | Recommended control limits mg/l | | |
|---|---|---|---|
| | Lower | Optimum | Upper |
| 50.0 - 53.7 | 0.9 | 1.2 | 1.7 |
| 53.8 - 58.3 | 0.8 | 1.1 | 1.5 |
| 58.4 - 63.8 | 0.8 | 1.0 | 1.3 |
| 63.9 - 70.6 | 0.7 | 0.9 | 1.2 |
| 70.7 - 79.2[2] | 0.7 | 0.8 | 1.1 |
| 79.2 - 90.5 | 0.6 | 0.7 | 0.8 |

[1]Based on temperature data obtained for a minimum of 5 years.

[2]Temperature range for the Hyder area.

Table IV-3. WHITEWING RANCH GROUND-WATER CHEMISTRY OF 1974 AND 1979

| | Na | | Mg | | Ca | | Cl | | $SO_4$ | | $HCO_3$ | | TDS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | '74 | '79 | '74 | '79 | '74 | '79 | '74 | '79 | '74 | '79 | '74 | '79 | '74 | '79 |
| Whitewing # 1 | 320 | 407 | 22 | 50 | 285 | 220 | 860 | 1004 | 203 | 298 | 127 | 66 | 1854 | 2599 |
| Whitewing # 2 | 205 | 259 | 10 | 10 | 61 | 45 | 308 | 362 | 120 | 203 | 137 | 87 | 877 | 1067 |
| Whitewing # 3 | 215 | 291 | 15 | 16 | 85 | 62 | 380 | 411 | 146 | 275 | 127 | 76 | 1017 | 1345 |
| Whitewing # 5 | 280 | 360 | 29 | 28 | 208 | 92 | 612 | 564 | 190 | 350 | 123 | 71 | 1562 | 1850 |
| Whitewing #13 | 210 | 215 | 16 | 10 | 82 | 35 | 192 | 253 | 143 | 173 | 142 | 100 | 995 | 962 |
| Whitewing #14 | 175 | 182 | 9 | 6 | 38 | 16 | 132 | 163 | 114 | 124 | 162 | 116 | 735 | 730 |
| Whitewing #15 | 147 | 152 | 2 | 3 | 18 | 9 | 136 | 117 | 68 | 89 | 152 | 110 | 542 | 595 |
| Whitewing #16 | 137 | 150 | 2 | 2 | 19 | 10 | 124 | 130 | 70 | 90 | 137 | 111 | 516 | 581 |
| Whitewing #17 | 143 | 142 | 2 | 2 | 14 | 7 | 188 | 111 | 60 | 81 | 137 | 105 | 493 | 483 |
| Whitewing #18 | 157 | 177 | 3 | 4 | 27 | 19 | 172 | 219 | 90 | 94 | 123 | 95 | 603 | 734 |
| Whitewing #19 | 152 | 169 | 4 | 4 | 22 | 16 | 140 | 212 | 62 | 84 | 137 | 97 | 562 | 715 |
| Whitewing #20 | 152 | 142 | 4 | 2 | 18 | 8 | 132 | 111 | 70 | 100 | 147 | 110 | 554 | 557 |
| Whitewing #22 | 152 | 150 | 4 | 2 | 21 | 10 | 228 | 134 | 64 | 91 | 147 | 113 | 550 | 573 |

Peterson (1968) conducted a gravity survey of the Hyder area, and the U.S. Geological Survey is now conducting a gravity survey just south of the area. Map IV-4 shows the residual aeromagnetic data of the area; contour intervals are 25 gammas. Magnetic highs are prominent in the Little Horn Mountains at the northwest end of the area and in the northern end of the Gila Bend Mountains, 30 kilometers north of Hyder. In a general way, the gravity contour lines follow the axial trends of the mountains. Magnetic intensity also tends to decrease from north to south across the study area. Two small gravity lows are within the area, one in the central portion of the Palomas Plain and the other on the northeastern side of the Tank Mountains. A 300 gamma magnetic low occurs just south of the Palomas Mountains.

The residual Bouguer gravity map (Map IV-5) is contoured on 5 mgal intervals. The major gravity low is located north of Baragan Mountain in the Palomas Plain, and a small gravity low occurs about 5 kilometers south of the Horn.

A seismic profile across the smaller gravity low was constructed by Exxon geologists (Eberly and Stanley, 1978). Figure IV-1 shows the results of that survey as well as locating two oil and gas test holes. The basin thickness from these tests is estimated at 2,700 meters. True graben structures were encountered in the seismic survey and are indicated in Figure IV-1. The Palomas Plain gravity low should indicate 3,000 meters or more of Cenozoic material, but bedrock outcrop

within the low may substantially reduce this estimate. Density contrasts between bedrock and basin material would best explain the differences between the two gravity anomalies.

5. Water Temperatures and Gradients. Most of the wells completed in the Hyder area are used for irrigation of cotton, grapes, wheat and citrus crops. Approximately 250 wells were reviewed, either in person or through a literature search. The majority of these wells were completed to a depth of less than 100 meters. Table IV-4 lists 88 sites where natural waters have temperatures greater than 30°C. Ten of the wells have temperatures of 40°C or greater. All known discharge temperatures are shown on Map IV-6.

Simple temperature gradients were calculated by subtracting the mean annual air temperature from the water temperature, then dividing the result by the reported depth of the well. A mean annual air temperature of 22.4°C was selected from Druitt's (1976) map. The metric system was used throughout and the results were recorded in °C/km. Only those wells whose depths were in excess of 100 m were used so as to eliminate gradients that might be influenced by near-surface thermal phenomena or ground-water recharge. Results were grouped as to gradient range and plotted on Map IV-7. These values should be viewed as minimum temperature gradients as they assume 100 percent of the water coming from the deepest penetration of the well. No provisions were made for mixing of waters from different aquifers or for depth at which the pumps were set.

Table IV-4. Wells and Springs in the Hyder Area with Temperatures of 30°C or Greater

| Location | Temperature °C | Depth Meters | Map Quadrangle | Reference |
|---|---|---|---|---|
| (C-3-11)25cb | 48.9 | 401 | Hyder | 1 |
| (C-4-7)34cdc | 31.0 | 253 | Dendora Valley | 1,3 |
| (C-4-8)26add | 32.8 | 56 | Dendora Valley | 2,3 |
| (C-4-8)26ddd | 34.5 | 59 | Dendora Valley | 2,3 |
| (C-4-8)35bdd | 30.6 | 83 | Dendora Valley | 2,3 |
| (C-4-8)35daa | 30.6 | 65 | Dendora Valley | 2 |
| (C-4-8)35dbb | 30.3 | 68 | Dendora Valley | 2 |
| (C-4-10)3daa | 33.5 | 137 | Hyder | 1,2,3 |
| (C-4-10)5abb | 36.0 | 389 | Hyder | 3 |
| (C-4-10)5bbb | 34.0 | 300 | Hyder | 4 |
| (C-4-10)6bb | 36.7 | 305 | Hyder | 1 |
| (C-4-10)7bb | 35.0 | 196 | Hyder | 1 |
| (C-4-10)16abb | 31.5 | - | Hyder | 4 |
| (C-4-10)16bbb | 32.5 | - | Hyder | 4 |
| (C-4-10)17daa | 31.0 | - | Hyder | 4 |
| (C-4-10)17dbb | 30.0 | - | Hyder | 4 |
| (C-4-11)1aaa | 32.8 | 102 | Hyder | 5 |
| (C-4-11)2bbb | 39.5 | 162 | Hyder | 1,3,6,7 |
| (C-4-11)2bcb | 37.8 | 162 | Hyder | 1 |
| (C-4-11)5bbb | 40.5 | 142 | Baragon Mountains | 2,3,7 |
| (C-4-11)6aab | 37.8 | 143 | Baragon Mountains | 2,3 |
| (C-4-11)8bbb | 40.0 | 200 | Baragon Mountains | 3,4 |

| Location | Temperature °C | Depth Meters | Map Quadrangle | Reference |
|---|---|---|---|---|
| (C-4-11)11aba | 37.8 | 184 | Hyder | 1 |
| (C-4-11)11bab | 37.2 | 168 | Hyder | 1,7 |
| (C-4-11)12abb | 38.0 | 375 | Hyder | 1,7 |
| (C-4-11)12bbb | 35.0 | 126 | Hyder | 2,3 |
| (C-4-11)16bbb | 30.0 | 153 | Baragon Mountains | 1,3.7 |
| (C-4-11)21abb | 32.2 | 419 | Baragon Mountains | 1,3 |
| (C-4-11)21bbb | 30.5 | 397 | Baragon Mountains | 3 |
| (C-4-11)33bbb | 30.0 | 332 | Baragon Mountains | 4,7 |
| (C-5-7)1aaa | 31.0 | 214 | Vulture Mountains | 1,3 |
| (C-5-9)12acd | 32.8 | 189 | Aguila Mountains | 2,3 |
| (C-5-10)16bbb | 45.6 | 387 | Agua Caliente Mts. | 1 |
| (C-5-10)16bbc | 45.8 | - | Agua Caliente Mts. | 6 |
| (C-5-10)16cbb | 32.8 | 22 | Agua Caliente Mts. | 2,3 |
| (C-5-10)16cbc | 40.0 | 110 | Agua Caliente Mts. | 3,7 |
| (C-5-10)16ccb | 39.4 | 26 | Agua Caliente Mts. | 2,3 |
| (C-5-10)18cda | 34.5 | - | Agua Caliente Mts. | 3 |
| (C-5-10)19aa | 35 - 40 | Springs | Agua Caliente Mts. | 2 |
| (C-5-10)20dbd | 33.3 | 4 | Agua Caliente Mts. | 2,3 |
| (C-5-10)28dcb | 39.0 | 396 | Agua Caliente Mts. | 3,7 |
| (C-5-11)1dc | 31.7 | 275 | Agua Caliente Mts. | 1,7 |
| (C-5-11)2bbb | 39.0 | 305 | Agua Caliente Mts. | 2,3 |
| (C-5-11)4ab | 30.0 | 111 | Baragon Mountains | 1 |
| (C-5-11)11cab | 36.7 | 214 | Agua Caliente Mts. | 1,3 |
| (C-5-11)12cba | 31.1 | 30 | Agua Caliente Mts. | 2 |
| (C-5-11)15abb | 35.5 | 244 | Aztec NW | 2,3 |

| Location | Temperature °C | Depth Meters | Map Quadrangle | Reference |
|---|---|---|---|---|
| (C-5-12)3aa | 32.2 | - | Baragon Mountains | 6 |
| (C-5-12)4bcb | 30.2 | 113 | Baragon Mountains | 2,3,6 |
| (C-5-12)4bcc | 32.0 | 152 | Baragon Mountains | 4 |
| (C-5-12)4cbc | 30.0 | 95 | Baragon Mountains | 1,3,4 |
| (C-5-12)4cdb | 35.0 | 602 | Baragon Mountains | 4 |
| (C-5-12)4cdd | 34.0 | 518 | Baragon Mountains | 4,7 |
| (C-5-12)5aaa | 31.1 | 218 | Salome | 2 |
| (C-5-12)5aab | 30.5 | 43 | Salome | 1 |
| (C-5-12)5aad | 30.5 | 90 | Salome | 4 |
| (C-5-12)5abb | 32.0 | 542 | Salome | 4 |
| (C-5-12)9abc | 38.8 | 500 | Baragon Mountains | 6 |
| (C-5-12)9acc | 41.6 | - | Baragon Mountains | 6 |
| (C-5-15)9bbb | 32.0 | 171 | Baragon Mountains | 4 |
| (C-5-12)9cba | 42.5 | 503 | Baragon Mountains | 3,4 |
| (C-5-12)9cbc | 42.5 | - | Baragon Mountains | 3 |
| (C-5-12)9cca | 40.0 | 489 | Baragon Mountains | 4 |
| (C-5-12)15bcb | 33.3 | 154 | Aztec NW | 2 |
| (C-5-12)15cbd | 34.0 | 145 | Aztec NW | 1,3 |
| (C-5-12)15cca | 34.2 | 145 | Aztec NW | 1 |
| (C-5-12)16aab | 32.8 | 27 | Aztec NW | 1,3,7 |
| (C-5-12)16aa | 32.2 | 191 | Aztec NW | 1 |
| (C-5-12)16abb | 36.7 | 203 | Aztec NW | 4 |
| (C-5-12)16abb$_2$ | 32.0 | 122 | Aztec NW | 1,4,7 |
| (C-5-12)16aba | 37.8 | 196 | Aztec | 1,7 |
| (C-5-12)16acc | 33.3 | 282 | Aztec | 2 |

| Location | Temperature °C | Depth Meters | Map Quadrangle | Reference |
|---|---|---|---|---|
| (C-5-12)16ad | 33,3 | 154 | Aztec | 1,7 |
| (C-5-12)16ba | 35.0 | 226 | Aztec | 1,7 |
| (C-5-12)16baa | 35.0 | 245 | Aztec | 2,4 |
| (C-5-12)16bbb | 35.0 | 139 | Aztec | 2,4,7 |
| (C-5-12)21aad | 33.9 | 177 | Aztec | 1,7 |
| (C-5-12)21bb | 32.8 | 114 | Aztec | 1,7 |
| (C-5-12)21bbb | 33.9 | 136 | Aztec | 2,3 |
| (C-5-12)21bbd | 33.3 | 79 | Aztec | 2,3 |
| (C-5-12)22bbc | 34.4 | 174 | Aztec | 2 |
| (C-5-12)28aaa | 33.3 | 218 | Aztec | 2 |
| (C-5-12)33cda | 31.1 | 75 | Aztec | 1,3,7 |
| (C-5-12)35bbb | 30.8 | 148 | Aztec | 2.3 |
| (C-6-7)1bdd | 30.0 | - | Theba | 3 |
| (C-6-7)11abc | 31.0 | 375 | Theba | 3 |
| (C-6-7)11dcc | 31.0 | 282 | Theba | 3 |
| (C-6-7)12ccc | 33.0 | 423 | Theba | 3 |

References:


1. Giardina and Conley, 1978
2. Armstrong and Yost, 1958
3. U.S. Geological Survey, 1979
4. This report
5. Arizona Land Department, Open File
6. Swanberg and others, 1977
7. Weist, 1965

There are 73 wells within the Hyder area with recorded temperatures and whose depths exceed 100 meters. An additional 28 wells have been recorded with temperatures, in the literature, yet have been completed to depths less than 100 meters. Table IV-5 lists the arithmetic mean and weighted mean temperature gradients for wells less than 100 meters in depth, as well as those in the intervals of 100-200 meters, 200-400 meters, and in excess of 400 meters. The increase in depth reduces the magnitude of the average simple temperature gradient. This reduction is in response to the normal thermal behavior within the region as depicted in Figure IV-2.

The weighted mean temperature gradients as well as the ranges for each of the depth intervals are also depicted in Figure IV-2. Pumping records of those wells in excess of 400 meters indicate long and constant usage. The one exception is the Exxon oil test well in T.3S., R.11W., Sec. 25cb. Its total depth is 401 meters, bottom hole temperature 48.9°C, and the simple temperature gradient is 66.1°C/km. The geophysical logs for this hole were examined in the offices of the Arizona Oil and Gas Conservation Commission, Phoenix. The temperature increases with each successive measurement. Temperature equilibration had not been achieved by the end of the test.

Extensive water well sampling at the Whitewing Ranch was undertaken in April, 1979. The Na-K-Ca chemical geothermometer of Fournier and Truesdall (1973) was applied to these samples,

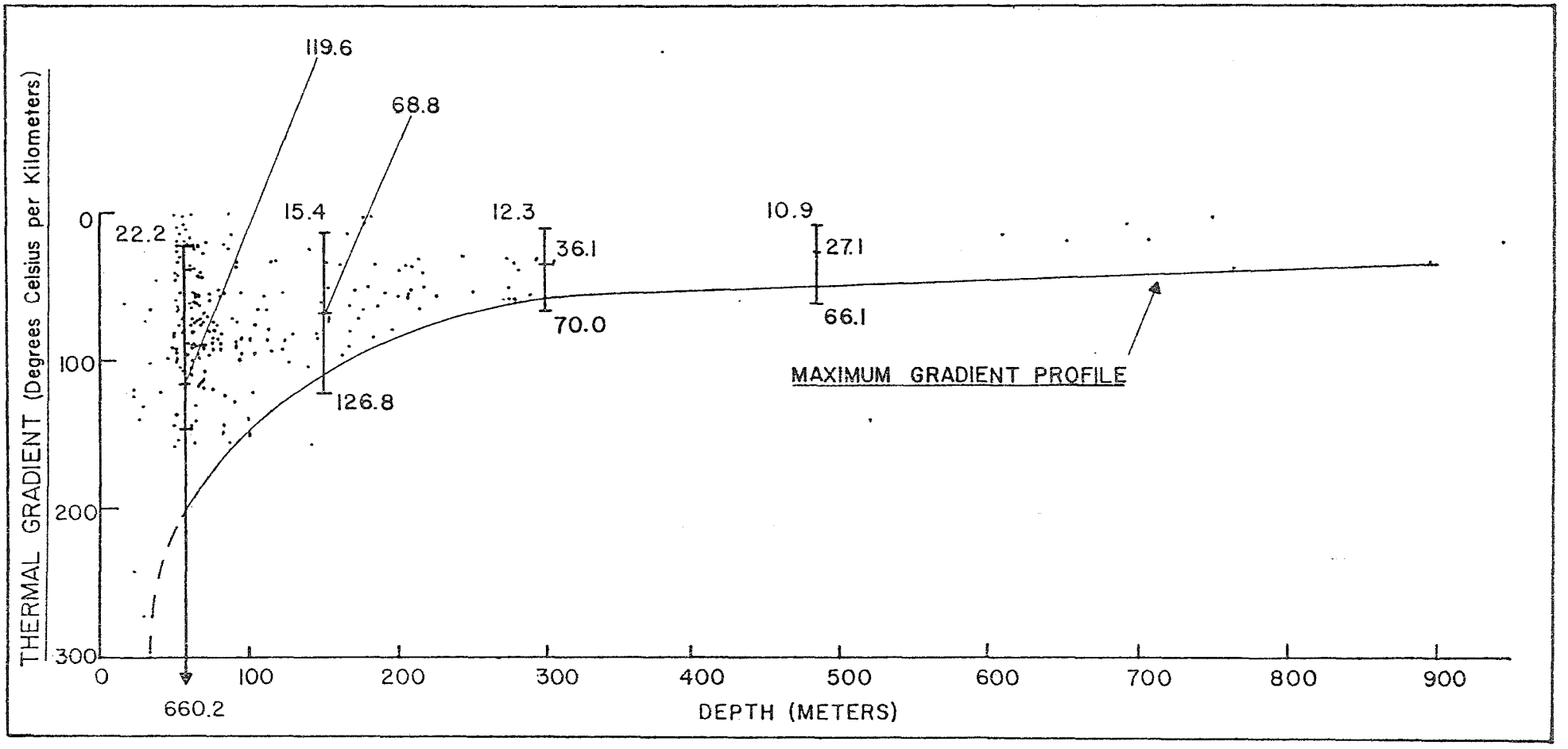


FIGURE IV-2. MAXIMUM GRADIENT PROFILE OF COCHISE COUNTY WITH GRADIENT RANGES FOR THE HYDER AREA (AFTER GIARDINA AND CONLEY, 1978).

Table IV-5. Temperature Gradients for Wells in the Hyder Area

| Interval (Meters) | Number of Wells | Average Depth (Meters) | Arithmetic Mean* Gradient (°C/km) | Weighted Mean** Gradient (°C/km) |
|---|---|---|---|---|
| 0 - 100 | 28 | 57.9 | 149.7 | 119.6 |
| 100 - 200 | 37 | 150.6 | 69.7 | 68.8 |
| 200 - 400 | 26 | 293.0 | 37.4 | 36.1 |
| >400 | 10 | 482.2 | 27.9 | 27.1 |

$$* \ \frac{\Sigma \text{ (Temperature Gradient)}}{\text{Number of Wells}}$$

$$** \ \frac{\Sigma \text{ (Temperature Gradient x Depth of Well)}}{\text{Depth of Well}}$$

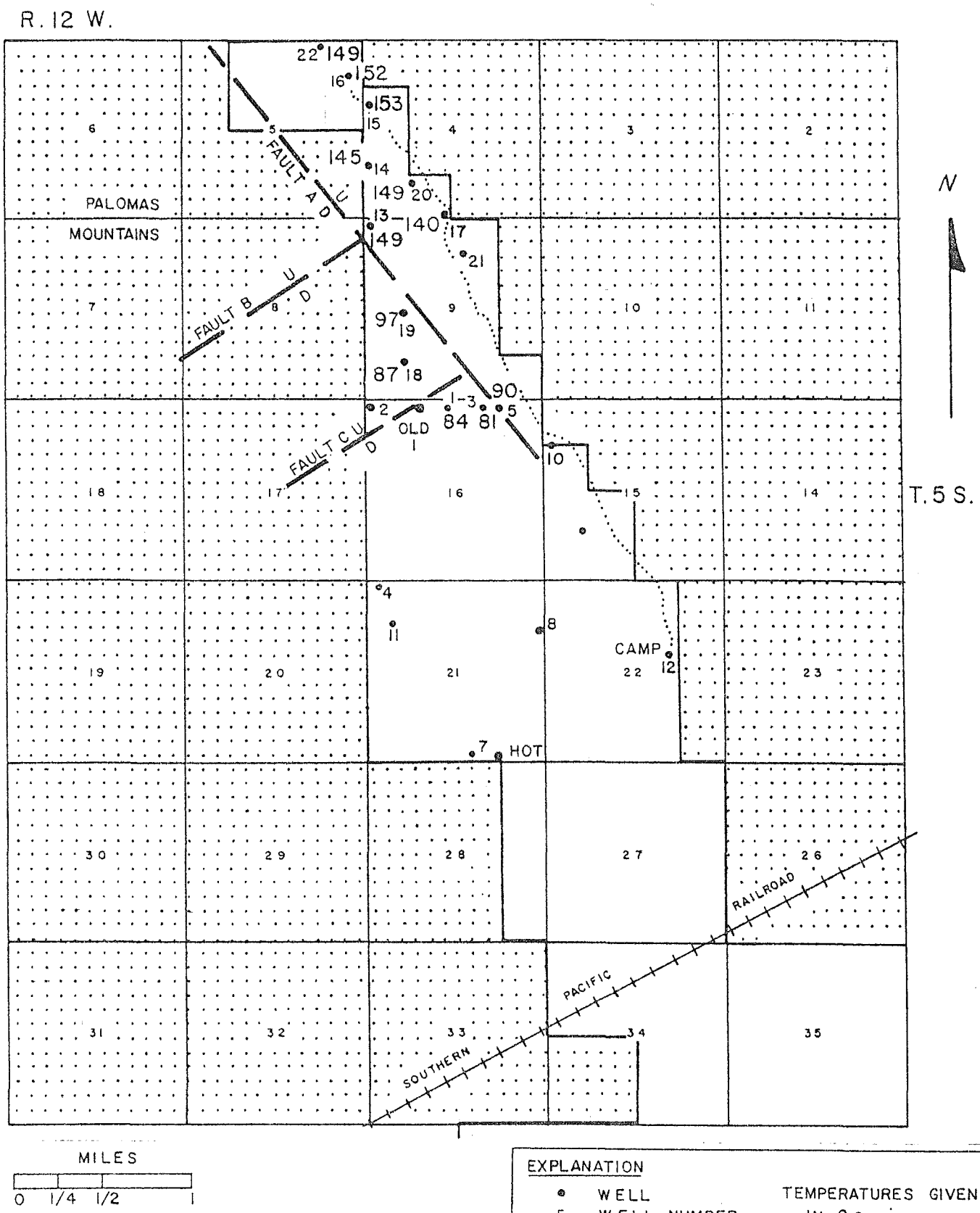


FIGURE IV-3. PROBABLE FAULTS ACROSS THE WHITEWING RANCH AND THE Na-K-Ca CHEMICAL GEOTHERMOMETERS. (AFTER MANERA, 1977).

and the results were plotted on the "Probable Fault Map" of Manera (1977). Figure IV-3 is Manera's map with the Na-K-Ca values added. The higher indicated temperatures (>100°C) are all east of the proposed northwest fault which fronts the eastern side of the Palomas Mountains. One must, therefore, conclude that there is a real structure separating the higher values from the lower temperatures and that this structure may provide through-going communication between a heat source and the shallow aquifers. A graben structure is inferred.

Elsewhere within the Palomas Plain there are similar geochemical indications of one or more deep heat sources. None is as well documented as around the Whitewing Ranch due to the lack of close-spaced wells.

D. Conclusions

1. Eighty-eight wells and springs within the Hyder area have reported temperatures in excess of 30°C. A complete inventory of the more than 250 wells will no doubt reveal additional warm or hot water occurrences.

2. Assuming normal temperature gradients, the deeper portions of the basin should contain waters within the 50 to 150°C range.

3. Abnormal temperature gradients occur along the margains of gravity lows or on the basin-side of inferred deep structures. The deep structures may provide communication between the heat source or sources and the aquifers which display the higher temperature gradients.

4. Areas of geothermal interest are: 1) the inferred deep portion of the basin north of Baragan Mountain, 2) the area just south of Horn, 3) the area south of Turtleback Mountain and Agua Caliente Mountain.

5. Additional studies of the existing water wells may help to further delineate the size and thermal properties of this geothermal resource area. Several seismic profiles similar to those run by the Exxon Corporation may reveal deep graben structures in the aforementioned areas of interest.

## V. HYDER VALLEY RESERVOIR ESTIMATE

The Hyder valley-Palomas plain area has been divided into four parts for purposes of the reservoir estimate. These four parts are the Horn area, the Agua Caliente area, the Palomas Plain, and about 657 $km^2$ of alluvial areas outside of the other three, more favorable areas. The water in the upper part of the groundwater basin is extensively used for municipal and agricultural supply, therefore, the upper 300 m of the groundwater basin has been excluded from the reservoir estimate.

Based on the description of Basin and Range structure and stratigraphy by Eberly and Stanley (1978), and the gravity map of Aiken (1975), this area is probably underlain by about 300 m of extrusive volcanic rocks under a cover of continental deposits ranging from 0 to 600 m in thickness, but averaging about 300 m. In the Horn area, the volcanics are absent and the younger continental sediments rest directly on about 1400 m of older, deformed continental sediments. These units rest on a basement complex composed of pre-Tertiary igneous and metamorphic rocks. Porosity and specific yield of the materials comprising the groundwater reservoir have been estimated using reasonable values for these rock types.

The total volume of water in storage in the groundwater reservoir below 300 m amounts to 60,600 $hm^3$. Recoverable water amounts to about 23,500 $hm^3$. Table V-1 summarizes the reservoir estimate.

Groundwater in this area may occur under unconfined, semi-

confined or confined conditions locally. Except in the Horn area, subsidence is not expected to be a problem. In the shallow parts of the groundwater basin, high salinity is not expected to be a problem. Geotechnical problems such as subsidence or high salinity might be encountered if water is mined from deep parts of the sedimentary section beneath the Horn area, but the extent of these problems cannot be estimated from the available data.

Table V-1. Hyder Valley - Palomas Plain

| Sediment Type | Thickness | Area | Porosity | Specific Yield |
|---|---|---|---|---|
| Horn Area | | | | |
| continental seds. | 1200 m | 122 $km^2$ | 20% | 10% |
| older cont. seds. | 1400 m | 122 $km^2$ | 10% | 3% |
| Agua Caliente Area | | | | |
| continental seds. | 0-150 m | 228 $km^2$ | 20% | 10% |
| volcanic rocks | 200 m | 228 $km^2$ | 5% | 1% |
| Palomas Plain | | | | |
| continental seds. | 600 m | 168 $km^2$ | 20% | 10% |
| volcanic rocks | 300 m | 168 $km^2$ | 5% | 1% |
| All Other Areas | | | | |
| continental seds. | 0-150 m | 675 $km^2$ | 20% | 10% |
| volcanic rocks | 150 m | 657 $km^2$ | 5% | 1% |

| | Water in Storage | Recoverable Water |
|---|---|---|
| Continental Seds. | 32,600 $hm^3$ | 15,200 $hm^3$ |
| Volcanic Rocks | 11,000 $hm^3$ | 2,200 $hm^3$ |
| Older Continenetal Seds. | 17,000 $hm^3$ | 5,100 $hm^3$ |

## VI. ENVIRONMENTAL ASPECTS

### A. General

So far the investigation of the Hyder area has not disturbed the environment. Field work involved location and sampling of existing water wells, irrigation wells, seeps and springs.

Should additional work in the area be required, it probably would not involve surface disturbance. Additional wells, especially the deeper ones, would have to be sampled. Geophysical techniques, such as close-spaced gravity determinations, may be needed to better define the extent of the basin. No surface disturbance is involved in such a survey.

If heat flow drilling is deemed necessary, the judicious selection of drill site or sites will minimize local impact. Since the area is currently being farmed, there is the likelihood of one or more drill sites being located in or adjacent to farm land. The impact on the natural or farm environment would be minimal and of short duration.

Should an economic resource area or areas be delineated within the Hyder area, appropriate care and concern will be taken to extract the geothermal heat and water. The problems associated with the development of geothermal resources within a heavily farmed area should be akin to those of developing new irrigation wells which do not contain the thermal energies. Brine and/or salt may be a by-product of the upgraded waters. Disposal or sale of these by-products will depend upon their

composition and quantity. Speculation on removal of these products from the surface environment will have to be deferred until such time as the chemical composition of the resource water is known.

Withdrawal of ground waters may also cause local subsidence. This is true whether the waters are thermal or not. In this respect, the development of the resource for its water content is no different than if one were to develop shallow irrigation wells of equal capacity. The main difference between the geothermal waters and the currently exploited irrigation waters (other than their thermal characteristics) is that the geothermal waters are deeper.

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