From: Final Report on U.S. Geological Survey Grant No. 14-08-0001-E-255, Evaluation of Geothermal Potential of the Basin and Range Province of New Mexico, Authorship uncertain. Electrical studies of Lightning Dock KGRA by G. R. Jiracek, in press (?).

roughly Road Well on the east and traversing beyond the hot wells (Figure 35). The self-potential survey was accomplished using a single reference electrode emplaced at Road Well, and repeatable readings were made on three consecutive days. The telluric survey using ∿300 m dipoles definitely shows the effect of the high resistivty ridge centered to the east of the hot wells, and there appears to be a negative SP anomaly of about 10 mV associated with the hot water zone (Figure 35). These results are compared in Figure 35 to the corresponding gravity profile and a segment of the total field mapping results from the E-W bipole transmitter (Figure 31).

Magnetotelluric Soundings.

Magnetotelluric soundings (Figure 28) in the Animas Valley were made in cooperation with Geonomics, Inc., Berkeley, California. The University of New Mexico cryogenic magnetometer sensor was used with the four channel analog recording system operated by Geonomics in 1976. Data were recorded over a period range of 0.1 to 100 seconds in two bands. Processing of the data was carried out in the standard fashion similar to that described below in the COCORP studies (p.); however, the vertical magnetic field was not recorded. As an example of the results, we have presented a pseudosection of the apparent resistivity versus period data for the ∿E-W principle direction in Figure 36. This direction would correspond to the transverse magnetic (TM) mode or the dip direction, since Basin and Range structure is predominately north-south. The TM mode results in greater change in apparent resistivity across a lateral discontinuity such as is clearly evident on the west side of the traverse (Figure 36). This reflects the sensing of the upthrown resistive block of the Peloncillo Mountains to the west; surprisingly the Pyramid Mountains to the east have not affected the results to any noticeable degree. The results to the east are dominated by a high resistivity closure (∿30 ohm-m) reflecting the high resistivity rhyolitic ridge. Perhaps from a geothermal standpoint, however, the most important aspect of the results may be a conductive zone (∿5 ohm-m) lying below the ridge in the section (Figure 36). Preliminary one-dimensional modeling places this conductor at a depth of about 7 km. This may represent the ultimate source of the Animas Valley thermal anomaly, possibly a basaltic magma body in the shallow crust. The nearest eruption of Pleistocene basalt is only 30 km southwest of the hot wells in T. 28 S., R. 20 W., Sec. 15.200. The northeast-trending line of basaltic centers that extend from the San Bernadino field of southeastern Arizona into the Animas Valley, a distance of 75 km, was noted previously.

The suggestion that a conductive body is present beneath the resistive ridge under the hot wells is based on a simple one-dimensional interpretation. We must also consider the possiblity that this conductive portion of the pseudosection is related to lateral conductive variations at about the same distance (5-10 km). Very shallow conductive regions are clearly present at such distances as is evident by the bipole-dipole and dipole-dipole results (Figures 30, 31 and 32). Therefore, we must reserve our final interpretation of the MT data until after we have completed two-dimensional modeling.

Conclusions

A conductive zone detected by magnetotelluric soundings may reflect a shallow crustal magma heat source for the Animas Valley thermal anomaly. A more definitive conclusion must await two-dimensional modeling, since lateral conductive zones, present in the valley, may explain the long period magnetotelluric data. Quaternary basalt has erupted only 30 km to the southwest; however, Dellechaie (1977) has presented geochemical data that indicate that although the thermal waters are heated in igneous and carbonate rocks, there is no evidence of igneous heating. This evidence is based on water geothermometry which shows the last equilibration temperature at about 160°C (Dellechaie, 1977). This agrees with the values measured by Swanberg (personal communication, 1977). As pointed out by Dellechaie, water circulation to a depth of more than 4 km would explain this temperature, assuming a regional gradient of 35°C/km. A crustal magma heat source would reduce the circulation depth necessary to explain the well-water chemistry.

The occurrence of the Animas Valley thermal anomaly appears to be controlled by the intersection of visible Basin and Range faulting and an older, Oligocene, cauldron ring-feature zone. This is substantiated by the recent detailed geologic mapping and the combined geophysical data. The observed electrical resistivity patterns are consistent with a localized heat flow anomaly exceeding 800 mWm^{-2} (20 HFU) (Lange, 1977; Dellechaie, 1977). All results point to a conduit-like ascension of thermal waters, controlled by fault intersections, which are dispersed northwesterly by shallow groundwater flow.

Given the diversity of information available for the Lightning Dock KGRA, we may estimate the heat content in the shallow reservoir. This proceeds as follows:

1) Volume estimated ∼ E-W extent of 1.5 km based on conductive anomaly measured by bipole-dipole, dipole--dipole, telluric and downhole-remote electrical results; estimated ∼ N-S extent of 2.5 km based primarily on the downhole-remote mapping; drilling results place the top of the aquifer at about 25 m and we estimate the average bottom depth to be ∼200 m based on dipole-dipole soundings. The volume of this shallow subsurface reservoir would thus equal 0.66 km^3. The discussion of the dipole-dipole results, Figure 34, included a justification for modeling a conduit-like extension of the near-surface conductive zone. Estimation of the volume of this extension is slightly over 0.1

km^3. This assumed reservoir extension is truncated at 1.5 km depth, which is about the limit of our dipole-dipole resolution (Figure 34). An overall estimate of 0.75 km^3 for the volume of the Lightning Dock KGRA reservoir is considered conservative, since the high heat flow pattern is reported to extend 3 km in length (Dellechaie, 1977) or possibly as much as 10 km (Lange, 1977).

2) Volumetric specific heat - porosity of the geothermal zone is estimated at 20-25 percent; this value is less than that estimated at Las Alturas Estates owing to a probable reduction in porosity caused by mineral precipitation from the cooling thermal waters. The volumetric specific heat would thus range from 0.65 to 0.70 cal/cm^3°C. The porosity estimate is not in agreement with a simple Archie's law calculation using the known water resistivity of 6.3 ohm-m; the bulk resistivity of the quifer of 4 ohm-m calculated from dipole-dipole modeling is assumed to reflect a high clay component.

3) Reservoir temperature above mean annual. Our data on average reservoir temperature are imcomplete. AMAX Exploration, Inc. has occupied at least 31 heat flow holes averaging less than 70 m depth. Some "very high gradients at shallow depths" were observed that became isothermal at depth (Dellechaie, 1977). High

near-surface gradients with a maximum bottomhole (25m) temperature of 102°C have also been reported by Summers (1976). As a working number we have simply chosen 100°C as representative of the entire reservoir and 17°C as the mean annual temperature.

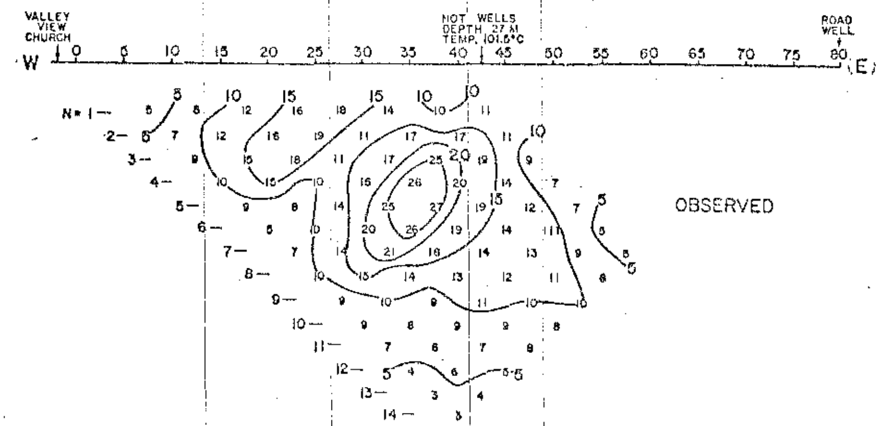
4) Approximate heat content calculation

Heat content = $\sim 0.8 \times 10^{15} \times 0.7\ (100-17)$ cal

Heat content $\simeq 0.05 \times 10^{18}$ cal

in the shallow reservoir.

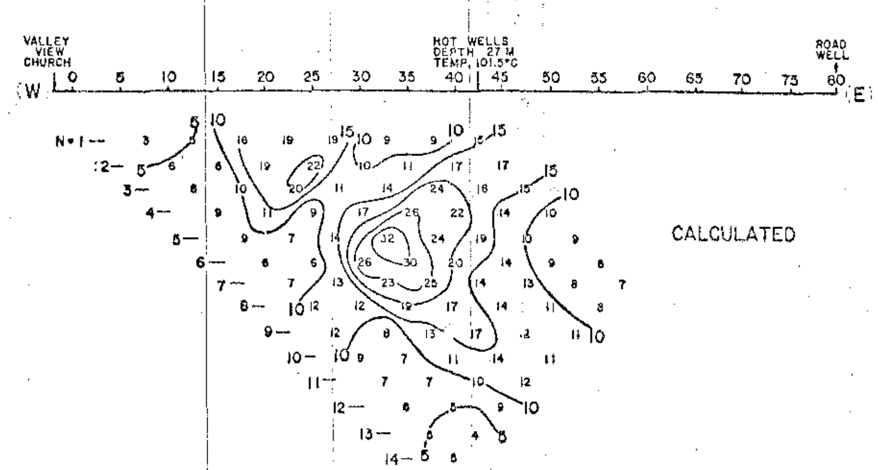
Note: This applies to the shallow reservoir only!
GRJ

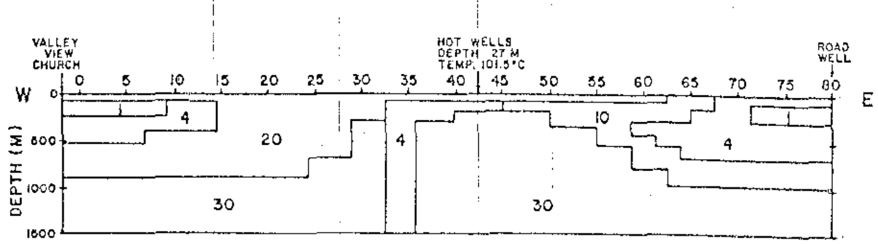


LIGHTNING DOCK KGRA
DIPOLE-DIPOLE PSEUDOSECTIONS

X=500 M, ρ_a IN OHM-M, C.I.=5 OHM-M

SCALE: 0 1000 2000 M





LIGHTNING DOCK KGRA
CALCULATED RESISTIVITY MODEL

RESISTIVITY IN OHM-M

SCALE: 0 1000 2000 M

Fig. 34

LIGHTNING DOCK KGRA - MT PSEUDOSECTION
(E ~ EW, ρ_a IN OHM-M)

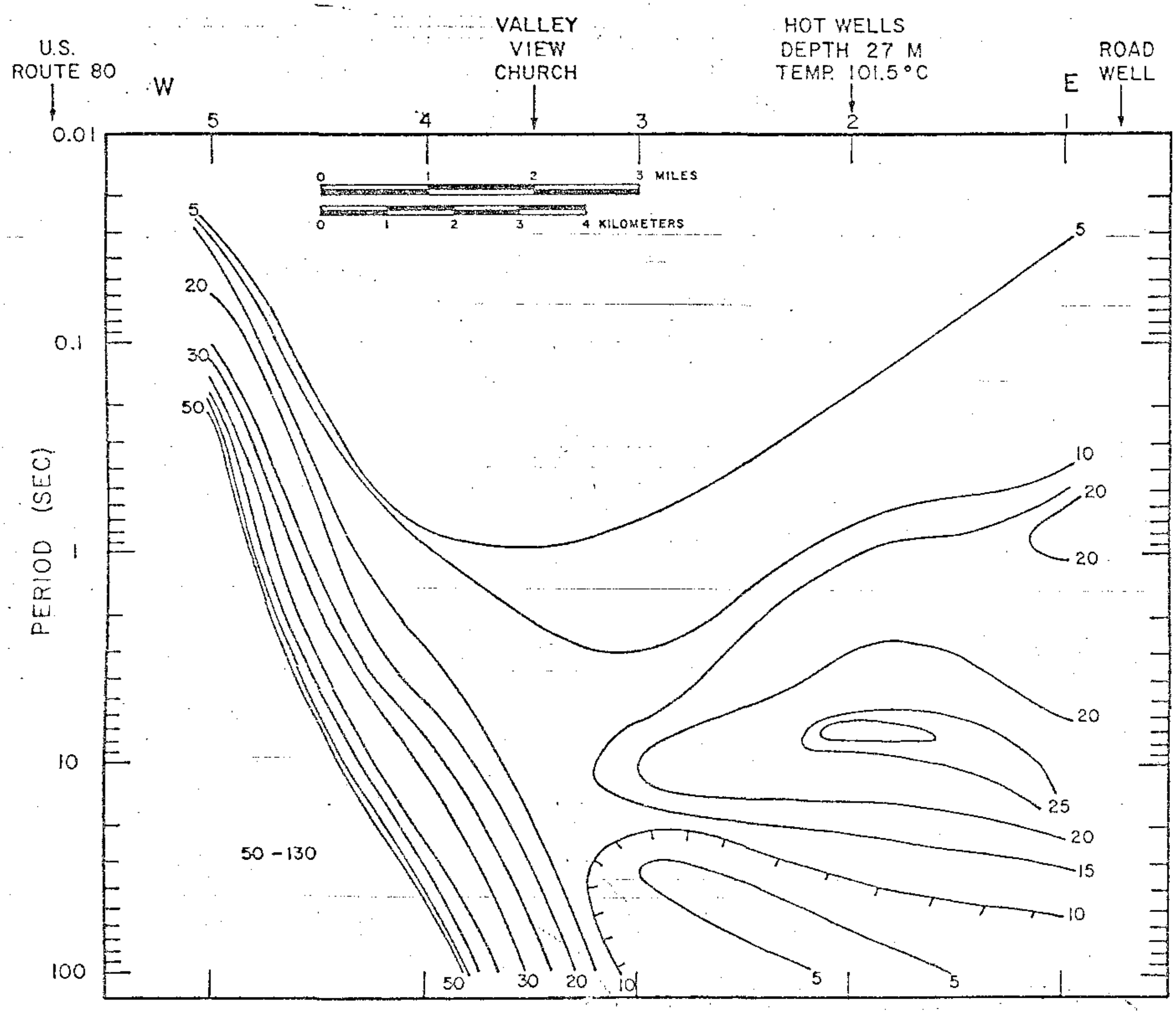


Fig. 36