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EXPLORATION AND DEVELOPMENT OF THE HEBER GEOTHERMAL FIELD IMPERIAL VALLEY, CALIFORNIA

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ABSTRACT

The Heber Geothermal field is located in Imperial County, California along the extension of the East Pacific Rise into the North American continent. Initial exploration in 1945 was for oil and gas but this changed to geothermal exploration when high thermal gradients were discovered in shallow holes. Several geophysical surveys were run: gravity, reflection seismic, ground noise, resistivity and spontaneous potential. However, the best data for picking the exploratory well location was provided by temperature holes up to 500 feet deep. The first geothermal well was drilled in 1972. Currently, the field is outlined by data from sixteen wells. These indicate a convective plume of hot water of 375°F or higher in a predominantly sand reservoir. A predominantly shale section provides a cap above 2,000 feet where heat flow is primarily conductive. Development, planned in zones from 2,000 feet to 10,000 feet, is expected to support a generating capacity of 500 megawatts for at least 30 years. Initial development will produce brine from zone 1 (2000-4000 feet) and zone 2 (4000-6000 feet). Producing wells will be directionally drilled to bottom hole targets in the temperature high. Cooled brine will be injected into wells located at the periphery of the reservoir. An operating unit has been formed by the leaseholders: Chevron Resources Company, Union Oil Company of California and New Albion Resources Company. Chevron is the Unit Operator and has signed a contract to supply 2-phase geothermal fluid to a 50 megawatt gross double-flash power generation plant to be built by Southern California Edison Company. Start-up for this--the first large commercial, privately financed, hot water geothermal power plant in the United States--is planned for early 1982.

INTRODUCTION

Heber is one of several geothermal fields undergoing development in the Mexicali-Imperial Valley between the Gulf of California and the Salton Sea. It is located between El Centro and Mexicali near the Mexican border (Fig. 1).

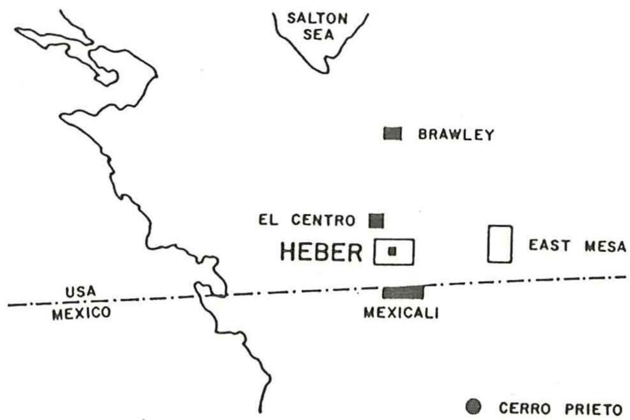

FIGURE 1. LOCATION OF HEBER GEOTHERMAL FIELD.

Other geothermal fields in the area include Cerro Prieto in Mexico, East Mesa, Brawley and Salton Sea. Geologically, the area is on a tectonic trend of postulated oceanic ridge segments and transform faults which extends from the East Pacific Rise at the mouth of the Gulf of California to the San Andreas fault in the vicinity of the Salton Sea (Fig. 2).

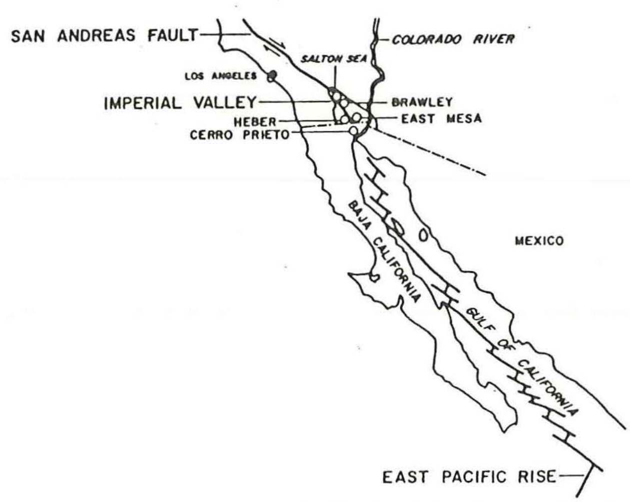

FIGURE 2. GULF OF CALIFORNIA - SAN ANDREAS FAULT TECTONIC SYSTEM.

This tectonic system has thinned the crust (Elders and others, 1972) in the Mexicali and Imperial Valleys so that regional heat flow is 2.5 H.F.U. or more (Blackwell, 1978).

EXPLORATION

Early exploration in the Heber area was for oil and gas. In 1945, Amerada drilled the No. 1 Timken to a depth of 6,637 feet just west of the town of Heber. The well did not discover hydrocarbons but there were indications that a thermal resource might exist. Large quantities of dry ice were reportedly used to cool the mud. Even so, a maximum temperature of 280°F was recorded on a Schlumberger E-log run.

Chevron conducted an extensive exploration program for oil and gas in the Imperial Valley in the early 1960's. This program included a gravity survey which indicated a positive Bouguer gravity anomaly just south of the town of Heber. In 1964, Chevron drilled several 500 foot holes in the Imperial Valley to investigate geothermal gradients. One of these holes was drilled on the Heber gravity anomaly. A gradient of 24.6°F/100 feet was measured between 400 and 500 feet and confirmed that the area was thermally anomalous. Consequently interest in Heber as an oil and gas prospect declined.

In 1970 Heber gained interest as a geothermal prospect because of the apparent success at Cerro Prieto in Mexico. A series of shallow holes (from 31 to 208 feet) drilled by the University of California (Riverside) indicated an anomaly of significant size as determined by contours of thermal gradients. Comparison of the Bouguer gravity map with the initial thermal gradient contours suggested that the gravity anomaly and the thermal anomaly were related (Fig. 3).

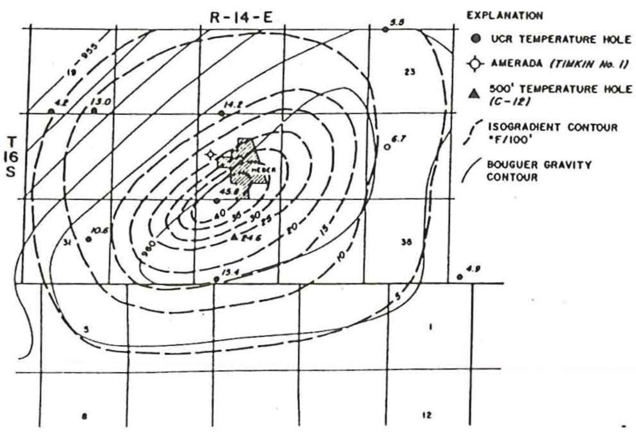

FIGURE 3. INITIAL SHALLOW ISOGRADIENTS AND BOUGUER GRAVITY CONTOURS - HEBER AREA.

However, the correlation shifted as more data became available (Fig. 4).

A north-south reflection seismic line was also shot in conjunction with the oil and gas exploration. The results were poor but suggested a very low relief, faulted, anticlinal reversal. This reversal has not been substantiated from well data but the E-log correlations used are not definitive.

Several geophysical surveys were run in conjunction with the geothermal exploration. Electrical resistivity data were obtained from a roving dipole survey, a dipole-dipole survey, and a magnetotelluric survey. The results were not diagnostic because the geothermal system at Heber does not have uniquely anomalous resistivities with respect to the one to five ohm-meter background resistivities in this part of the valley. A ground-noise survey provided an anomaly on the Bouguer gravity positive but the significance is questioned because of the generally high level of the surface noise. A weak anomaly was indicated just south of the town of Heber by a spontaneous potential survey. Unfortunately the anomaly lacked sufficient amplitude to distinguish it from other S.P. anomalies which lacked anomalous temperatures.

Early in 1972, Magma Energy, Inc. drilled the first geothermal well at Heber, the No. 1 Holtz, to a total depth of 5,147 feet. The results encouraged Magma to drill a second well, the No. 2 Holtz, a mile to the west. Chevron contributed financial support to the first well but not to the second.

Data from temperature holes, 200 to 500 feet deep, were the primary basis for locating Chevron's first deep test. A 1972 map of isotherms at 480 feet (Fig. 4) shows a well defined bulls-eye, centered at the northwest corner of Section 33.

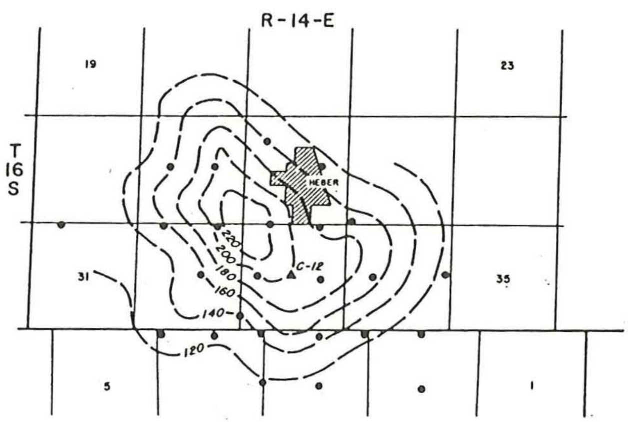

FIGURE 4. ISOTHERMS (°F) AT 480' (BLACK DOTS ARE CONTROL POINTS).

When gradient data are used to project isotherms to 5000 feet, a much broader target is seen (Fig. 5).

The gradient data suggested that the thermal anomaly shifted to the southeast with depth. Consequently, a location in the southeast part of the projected isotherm target was chosen.

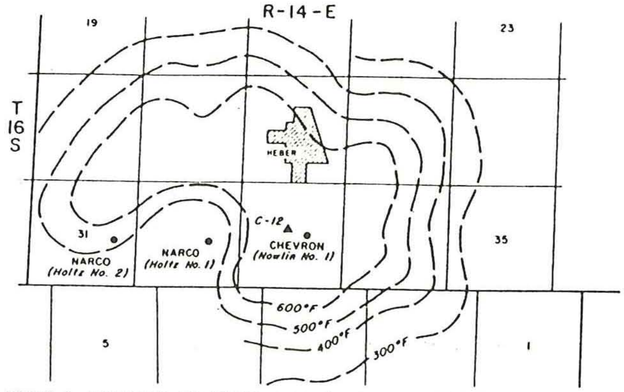

FIGURE 5. ISOTHERMS PROJECTED TO 5000' BASED ON 200' AND 500' GRADIENT HOLES. LOCATION OF CHEVRON-*NOWLIN No. 1* (CHEVRON'S FIRST DEEP TEST) IS SHOWN.

The Chevron No. 1 Nowlin was drilled in the fall of 1972. A maximum temperature of 368°F was recorded at 2,200 feet. This declined to 358°F at the total depth, 5,031 feet. Salinity of the water recovered from tests was fairly low (14,000 ppm total dissolved solids). Subsequent drilling has shown that if the well had been drilled in the northwestern part of the area defined by the projected isotherms at 5000 feet, it would have been well off on the flank of the deep thermal system.

FIELD DEVELOPMENT

Data from sixteen wells (including the Amerada No. 1 Timken, drilled for Oil and Gas) now define the Heber Geothermal Field (Fig. 6).

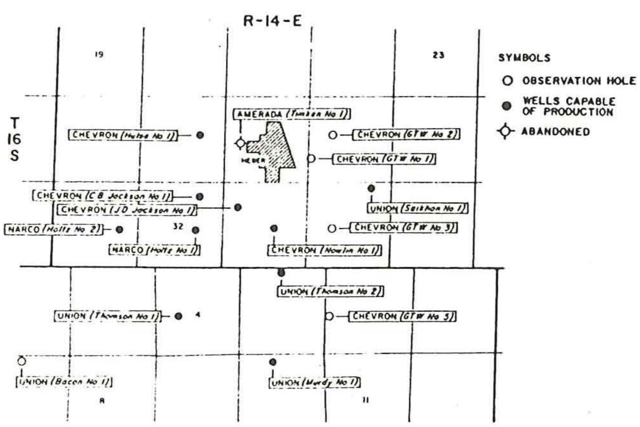

FIGURE 6. WELLS DRILLED IN THE HEBER GEOTHERMAL AREA.

The wells range in depth from 3,002 to 9,701 feet. All of the geothermal wells were drilled to evaluate and delineate the reservoir. They outline a convective plume of hot water of 375°F (191°C) or higher rising from depths below 10,000 feet. A component of horizontal flow shifts the plume northerly above 4,500 feet, giving it an overall shape of a lopsided mushroom. At 2,000 feet the plume centers near the Chevron No. 1 Nowlin but shifts about 1/2 mile south at 4,000 feet (Fig. 7).

Above 2,000 feet, cap rock is provided by a generally shaley section where heat flow is predominantly conductive. Below 2,000 feet sands predominate with intergranular porosities of 15 to 30%. Only three of the wells are in suitable locations to be used as producers or injectors in the planned commercial development of the field. The others will be used as observation wells to monitor reservoir temperature and pressure as the reservoir is developed.

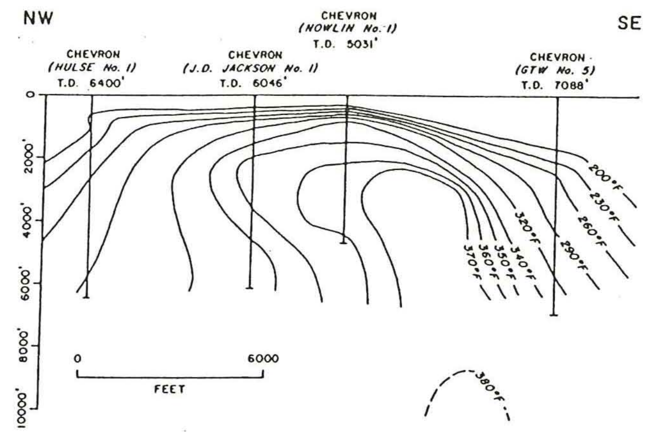

FIGURE 7. NW-SE CROSS SECTION SHOWING ISOTHERM CONFIGURATION.

Data needed to predict reservoir capacity and performance has been obtained through extensive well testing using various development schemes. The predicted reservoir capacity of 500 megawatts was established initially with a two-dimensional layered stream tube simulator model and secondly using a three-dimensional radial single phase water flow numerical simulator (Tansev and Wasserman, 1978).

The development plan was selected to optimize heat recovery and to support a generating capacity of 500 megawatts for about 30 years from the Heber thermal anomaly. Approximately 7,400 acres of land under lease to Chevron, Union Oil Company and New Albion Resources Company has been unitized with Chevron as Unit Operator. Wells will be directionally drilled for production from surface islands into the high temperature part of the thermal anomaly. Bottom hole locations will be evenly distributed in a circular pattern having a radius of about 2,000 feet. The power plants will be located near the producing islands to minimize heat loss during transit of the hot brine. Cooled brine will be moved from the power plants in pipelines, 30 to 42 inches in diameter, to injection islands on the periphery of the field. There, 1-1/2 to 2-1/2 miles from the center of the anomaly, the spent brine will be reinjected through directionally drilled wells to the present position of the 265°F isotherm. Simulated reservoir studies have shown that this production and reinjection pattern will provide the maximum economic reservoir life for the field. Imperial County has rezoned an area approximating 7,300 acres to allow the surface operations required to develop the Heber field (Fig. 8).

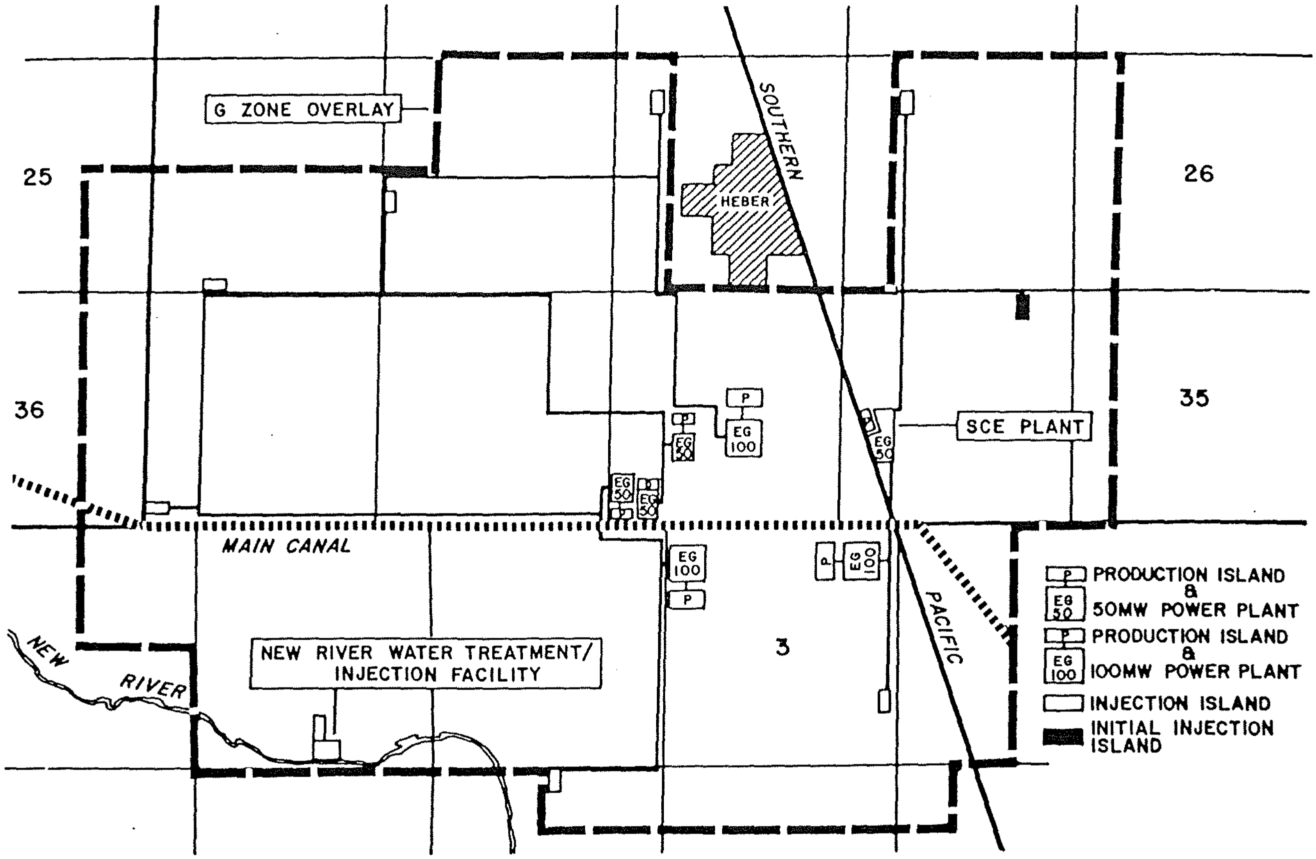

FIGURE 8. PRELIMINARY DEVELOPMENT PLAN-HEBER GEOTHERMAL FIELD.

Intervals of production and injection are limited to 2,000 feet to allow for a proper balance between the well bore and the reservoir flow capacity. Four production/reinjection zones have been defined for the 500 megawatt plan. Zones are 2,000 feet thick and extend consecutively from 2,000 feet to 10,000 feet. The first plants will use brines produced and reinjected into zone 1 (2,000-4,000 feet) and zone 2 (4,000-6,000 feet).

A fuel sales contract was signed by Chevron and Southern California Edison Company in November 1978 to supply 2 phase geothermal fluid from the Heber Unit to a 50 megawatt gross double flash power generation plant to be built by Edison. Startup is planned in early 1982 for this--the first large commercial, privately financed, hot water geothermal power plant in the U.S. Subsequent power developments are expected to occur in 50-100 megawatt increments with the total development of 500 megawatts completed in 1989.

ACKNOWLEDGMENTS

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