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PREFEASIBILITY GEOTHERMAL ASSESSMENT OF PLATANARES,
DEPARTMENT OF COPÁN, HONDURAS

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ABSTRACT

The Platanares geothermal system is located in a region of active Quaternary tectonism in western Honduras. Although the geothermal area is partially blanketed by Miocene ignimbrites (14.5 m.y.), there are no nearby Quaternary volcanic rocks to act as a young magmatic heat source. No acid-sulfate waters, indicative of vapor-dominated conditions, exist in the area. Hot spring activity is most vigorous along a 2 km stretch of the Quebrada del Agua Caliente fault zone. Natural discharge is high (~3300 l/min), temperatures range from 35 to 100°C, pH ranges from 7 to 9, and total dissolved solids are low (~1100 mg/kg). Chemical geothermometers indicate a subsurface reservoir temperature of about 225°C. Three exploration core holes (7.8 cm diameter) have been drilled to a maximum depth of 680 m and maximum temperature of 165°C. Two holes produce copious amounts of water under artesian conditions (~500 l/min max.; 5 bars flowing) from fractured red beds of Cretaceous to Eocene age (Valle de Angeles Group). Maximum power output is ~4.5 MW (thermal) but CO₂ released during flashing formed some aragonite scale in one hole. The third core hole has an "apparent" conductive gradient of 139° C/km at 400 m. Downward continuation of this gradient implies that the minimum depth to the geothermal resource (225°C) is 1.5 to 2.0 km.

INTRODUCTION

Geothermal efforts in Honduras are part of a coordinated effort among the Empresa Nacional de Energía Eléctrica (ENEE), the U.S. Geological Survey (USGS), and the Los Alamos National Laboratory (LANL) and their consultants to locate, evaluate, and develop a geothermal resource for electrical power generation. Initial studies (1985 to 1986) focused on ten areas: Platanares, San Ignacio, Azacualpa, Choluteca region (Pavana), La Ceiba region (Sambo Creek), El Olivar, Isla de Aguas Calientes, San Francisco de Ojuera, El Cajon Dam, and Agua Caliente (west of San Ignacio) (Fig. 1). Further evaluation

Fig. 1: Map of Honduras showing locations of major geothermal sites (large triangles) and other hot spring areas (small triangles) sampled during our investigations from 1985 to 1987.

during 1986 concentrated on the three sites having the best apparent potential: Platanares, San Ignacio, and Azacualpa. From these studies Platanares was chosen as the best site for geothermal development because of relatively high estimated subsurface reservoir temperatures ($\sim 225^{\circ}\text{C}$), large natural discharge of the hot spring system (~ 3000 l/min), and well-defined structural setting. In late 1986 to middle 1987, three slim core holes were drilled at Platanares to obtain information on the geothermal gradient hydrothermal alterations, fracturing, and possible inflows of hydrothermal fluids. The object of this paper is to briefly outline the results of our studies at Platanares. Reports on the area have been presented by Heiken et al. (1986; 1987), F. Goff et al. (1986; 1987a; 1987b; 1988), S. Goff et al. (1987; 1988), Laughlin et al. (1988), Truesdell et al. (1987a; 1987b), Hoover and Pierce (1988), and Bargar (1987).

GEOLOGIC BACKGROUND

The Platanares geothermal site is located along the Quebrada del Agua Caliente about 16 km west of Santa Rosa de Copán. The region around Platanares is mountainous and deeply dissected. Elevations of nearby ridges exceed 1400 m, whereas the hot springs in the Quebrada are at 700 to 800 m. A gold mine is actively being worked in the village of San Andres and an antimony mine (El Quetzal Mine), which is no longer being worked, lies about 4 km north of San Andres (Fig. 2).

Rocks in the Platanares area consist of Paleozoic schists and gneiss in the north, which are juxtaposed along the La Bufa Fault against Oligocene to Miocene andesites, basin-fill sedimentary rocks, tuffs and tuffaceous sedimentary rocks to the south. Late Cretaceous to Eocene red beds and conglomerates of the Valle de Angeles Group lie in fault contact with both Paleozoic and Tertiary rocks west, east, and northeast of the geothermal area and unconformably underlie tuffaceous rocks in the Quebrada de las Juniapas 1 km east of the area.

The geothermal area is highly faulted and fractured and occupies a structural graben trending in a northwest direction. Of primary importance are La Bufa Fault, which marks the northern limit of hot spring activity, and the Quebrada del Agua Caliente fault zone, which controls the discharge of 95% of the hot springs in the area. Hydrothermal alteration in the area varies from intense to non-existent. Intense alteration (argillic to phyllic grade) occurs in the San Andres mine, the El Quetzal Mine, along the Quebrada del Agua Caliente fault zone, along the Rio Lara and other faults within the structural graben, and within the PLTG-1 and PLTG-3 core holes. At least two hydrothermal events have affected the area: an early (Oligocene to Miocene?) event associated with Au, Hg, Sb, As, and Cu mineralization and quartz veins at the mines and in the creeks, and the present hydrothermal event.

Fig. 2: Simplified geologic map of the Platanares geothermal site showing locations of major hot spring areas and three exploration core holes in relation to rock units and structure.

GEOPHYSICAL INVESTIGATIONS

Detailed gravity survey results generally support the location of mapped faults. Steep gravity gradients clearly define the Agua Caliente fault zone. A positive gravity anomaly trends NE, intersecting the Quebrada del Agua Caliente between two of the gradient boreholes and is interpreted as being the result of an andesitic intrusion or stack of andesitic flows. The natural-source electrical (audiomagnetotelluric sounding and multifrequency telluric traversing) surveys indicate very low resistivities (<10 ohm-m) throughout the Platanares survey area. The depth of exploration is shallow, i.e. less than 300 m, identifying the shallow, more permeable areas where geothermal fluids are present.

The low resistivity data identifies a large area coincident with the Quebrada del Agua Caliente fault where relatively unmixed waters ascend. The lowest resistivities lie east of the fault, but because of the scarcity of data in this direction, there is not closure to this low-resistivity zone. A second large area (0.3 km²) of very low resistivity occurs about 500 m WSW of the second gradient core hole. This anomaly appears to coincide with several faults and fault intersections along which fluids could be ascending although there are no geothermal manifestations seen in this area.

THERMAL FEATURES AND HYDROGEOCHEMISTRY

Most of over 100 thermal springs and seeps, varying from 35°C to slightly superheated, discharge near river level along both the Quebrada del Agua Caliente and Rio Lara with the greatest number along a 1 km stretch downstream from the waterfall. All boiling springs are depositing silica sinter. No single hot spring has a flow exceeding 150 l/min but the combined discharge along the Quebrada averages >3000 l/min, which can raise the temperature of the river to about 40°C during dry seasons.

Thermal waters are Na-K HCO₃-SO₄-Cl in character with significant concentrations of As, B, F, Li, and NH₄ and low concentrations of Ca and Mg. Total dissolved solids are only 1100 mg/kg. Stable isotope data indicate that recharge to the geothermal reservoir comes from local precipitation and very anomalous concentrations of B, SO₄, and NH₄ and a ¹³C-CO₂ signature of ~11‰ indicate the geothermal reservoir is equilibrated in red beds of the Valles de Angeles Group. Good agreements exist between cation, ¹⁸O-SO₄, and gas geothermometers, suggesting a reservoir temperature of 225°C, possibly as high as 240°C.

EXPLORATION CORE HOLES

We drilled three slim exploration diamond core holes to depths of 650, 428, and 679 m, respectively at the Platanares site during the last stages of the prefeasibility study. PLTG-1, located along a part of the Quebrada with very few hot springs and PLTG-3, located within the area of most vigorous hot spring activity, bottomed in the hydrothermally-altered shales and conglomerates of the Valle de Angeles Group.

Fractured zones in PLTG-1 at 252 m, 574 m, and 625 to 644 m produce large amounts of hydrothermal fluids. A very large water entry was encountered at only 26 m in PLTG-3. Other large water entries in this hole were encountered at depths of 459 m and 622 to 635 m.

TEMPERATURE LOGS

The temperature logs for the three boreholes are shown in Figure 3. The bottomhole temperature of 160°C in PLTG-1, which persists all the way up to a depth of 350 m, is caused by heating during flow in the wellbore. The log from PLTG-2, which produces only very small quantities of water, displays two zones of linear (conductive) gradients separated by a perturbed zone at about 170 m, which is assumed to be caused by lateral flow of water around the casing at this horizon. The lower gradient is 139°C/km. The temperature of 163.9°C at total depth in PLTG-3 is considered to be slightly low because of insufficient time to let the well bore equilibrate.

Comparing the temperature gradients with the boiling point curve for pure water shows that the subsurface temperatures lie well within the field for liquid water and that the reservoir is liquid dominated. There is no evidence for a well-defined cap rock to the system or for a sudden increase in temperature to occur beneath PLTG-1 and PLTG-3. If a deeper reservoir at 210°C to 240°C underlies the Platanares area, as suggested by chemical geothermometry, the temperature gradients suggest that the minimum depth to the source geothermal reservoir is at least 1.5 to 2.0 km.

FLOW TESTING PLTG-1 AND PLTG-3

Although the exploration core holes were never intended to be production wells, they do produce copious amounts of water. In February and June of 1987 Los Alamos, ENEE, and USGS staff were on site at Platanares to collect fluid samples and perform flow tests on PLTG-1 and PLTG-3 to obtain information on aquifer chemistry and flow characteristics. The 8-day flow test of PLTG-1 showed a gradual decrease in flow rate to about 100 hours and then a sudden decrease in flow rate to about 190 hours. When the surface flow pipes and valves were dismantled after this test, we found aragonite scale lining the wellhead area of the flow equipment. A similar test performed on PLTG-3 did not produce scale after 10 days of flow. We believe that higher flowing pressure in PLTG-3 (70 psia as opposed to 30 psia in PLTG-1) prevented the scaling problem. PLTG-1 and PLTG-3 are exploration core holes, not intended to be production or test wells. We did however estimate the maximum thermal power from our flow data to be 3 MW(t) and 4.4 MW(t) for PLTG-1 and PLTG-3, respectively.

Fig. 3: Plot of temperature versus depth for the temperature logs compared to the boiling curve for pure water.

RESERVOIR MODEL, CONCLUSIONS AND RECOMMENDATIONS

Figure 4 presents a reservoir model of the Platanares system. Our data indicate that geothermal water is probably equilibrating in the Valle de Angeles Group of Cretaceous to Eocene age. Geochemical data indicate that the source reservoir has an equilibrium temperature of 225 to 240°C with more than 95% of reservoir fluids discharging among the Quebrada del Agua Caliente fault zone. The northern limit to the system is La Bufa Fault that juxtaposes Paleozoic schist against Tertiary volcanic rocks and Cretaceous to Eocene red beds. The reservoir appears to underlie an area of at least 3.5 km². The thermal gradient data suggest that the minimum depth to a reservoir of 225°C is 1.5 to 2.0 km. It is likely that temperatures of 225°C occur at depths of at least 2 km.

Flow test data from PLTG-1 and PLTG-2 indicate that fluids of 160 to 165°C are easily produced from fractured andesite and metaconglomerate along the Quebrada del Agua Caliente fault zone. Scaling of aragonite in the upper casing of PLTG-1 resulted from flashing and release of CO₂ because of lower flow rates and flowing pressures compared to PLTG-3. Downhole pumps and/or a binary-cycle heat extraction system could probably prevent scaling if the relatively shallow 160°C resource is developed.

The Los Alamos/USGS team submitted a recommendations report to ENEE in early 1988 (Laughlin, 1988). This report recommends that feasibility stage assessment begin at Platanares. It is recommended that the 160°C resource be developed using binary generators. Results from this production drilling would be integrated with existing data to site a 2 km test-for-discovery well to locate the predicted 225 to 240°C resource.

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Fig. 4: Schematic northwest-south cross-section of Platanares geothermal site; rock symbols same as on Fig. 2 except Qal=Quaternary alluvium and Qt=Quaternary terrace gravels. A postulated reservoir model is shown as are the temperature of major fluid entries in the core holes.

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