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GEOTHERMAL RESOURCES DEVELOPMENT IN COSTA RICA

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ABSTRACT

The first evaluation of the geothermal resources of Costa Rica was made during 1963-1964 by experts from the United Nations and the first pre-feasibility study was made in the Guanacaste Province during 1975-1976. A national reconnaissance resource study, carried out during 1989 and 1991 (ICE, 1991), indicated that the possible total geothermal potential of the country was about 900 MWe. The first deep geothermal exploratory wells in Costa Rica were drilled at the Miravalles geothermal field in 1979-1980 and the first geothermal power plant of 55 MW was commissioned in 1994 (Unit 1, Miravalles). Since then, the installed capacity has grown from 55 MWe (1994) to 163 MWe (2007). Two geothermal systems, one associated with the Tenorio volcano and the other with the Rincón de la Vieja volcano, have been studied and several deep exploratory wells have been drilled in these areas. Additionally, the contributions of different energy sources to the electricity system of Costa Rica will be presented here.

1. RESOURCE ASSESSMENT

Costa Rica is located in the southern part of the Central American isthmus, between Nicaragua and Panama. The country extends over an area of approximately 51,100 km^2 and has a population of about 4.4 million. In the early 1970s, Costa Rica satisfied its electricity needs using hydro (70%) and thermal (30%) energy sources.

The first evaluation of the geothermal resources in Costa Rica was made during 1963-1964 when, at the request of ICE, a mission of experts from the United Nations recommended that a detailed study should be carried out at Las Pailas (on the slope of the Rincón de la Vieja volcano) and at Las Hornillas (on the slope of the Miravalles volcano).

The first technical studies were made from 1975 to 1988 and comprised of three phases:

1. The pre-feasibility study of Guanacaste Province (1975 - 1976)
2. Electric power generation and resource assessment (1977 - 1980)
3. Feasibility studies of the Miravalles geothermal field (1983 - 1988)

The country was characterized in the reconnaissance study, carried out from November 1987 to January 1989, by ICE and Electroconsult (Figure 1) followed by the pre-feasibility study of the Tenorio Area. The final report, issued in November 1991 and entitled “Evaluación del Potencial Geotérmico de Costa Rica”, ranked various areas of geothermal interest in the country (Figure 1), and indicated that the possible total geothermal potential of Costa Rica was about 900 MWe.

In 1995 the feasibility study for Units 3 and 4 was made in Miravalles by ICE and Electrocounsult and the pre-feasibility study at Las Pailas was done by ICE and Geothermex from 1999-2001.

Las Pailas feasibility study was carried out first by West Japan Engineering Consultants in 2003 and by GeothermEx, in 2005, both feasibility studies conclude that "it is feasible to install a 35 MW power plant."

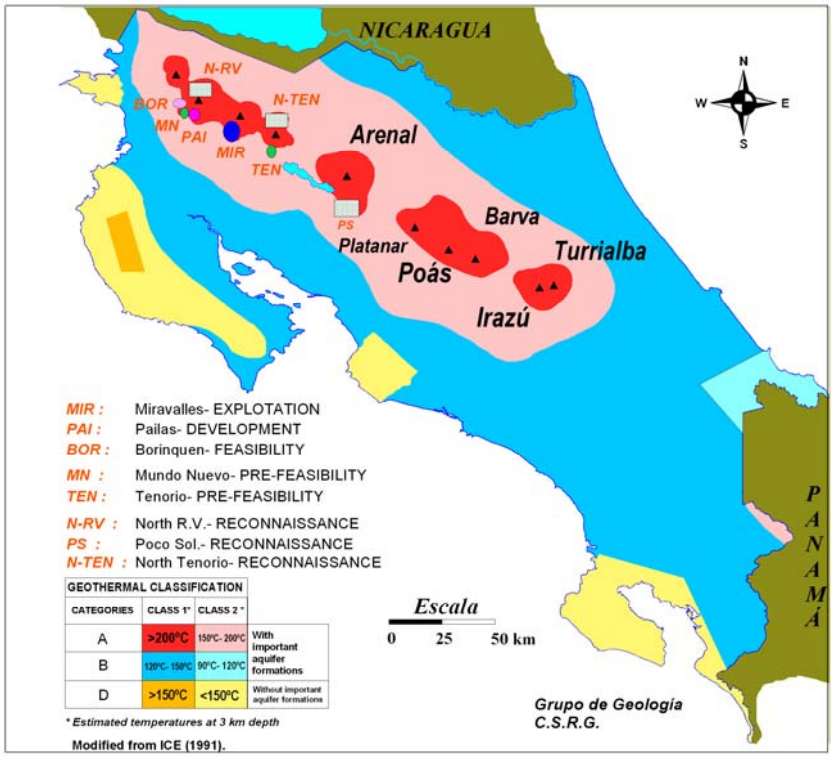

FIGURE 1: Geothermal resources in Costa Rica

Commercial production of electricity using geothermal steam began at Miravalles in early 1994, when Unit 1, a 55 MW single-flash plant, was commissioned. Unit 2, the second 55 MW plant, started production in August 1998. Regardless, in order to use the steam available from geothermal wells previously drilled for Unit 2, a 5 MW wellhead unit, located in the centre of the main production zone, was placed online at the end of November 1994 and additionally, two 5 MW back-pressure plants were rented from the Comisión Federal de Electricidad (Mexico) from September 1996 to April 1999. In March 2000, Unit 3, a 29 MW, a single-flash private plant, started delivering electricity to the national grid, and finally Unit 5, a 19 MWe binary plant came on line in 2004 (Table 1).

The 5 MWe back pressure wellhead unit was moved from the centre of the production zone to well PGM-29 in the year 2006 to reduce the steam extraction from the centre of the field.

TABLE 1: Units at the Miravalles geothermal field

Plant name	Power (MW)	Owner	Start-up date	Shut-down date
Unit 1	55	ICE	3/1994	
WHU-1	5	ICE	11/1994	
WHU-2	5	CFE	9/1996	4/1999
WHU-3	5	CFE	2/1997	4/1998
Unit 2	55	ICE	8/1998	
Unit 3	29	ICE (BOT)	3/2000	
Unit 5	19	ICE	1/2004	

2. CURRENT SITUATION

2.1 Exploitation phase

The Miravalles Geothermal field is a unique field under exploitation in Costa Rica which began to generate electricity in 1994 with 55 MWe. Currently, the total installed capacity of Miravalles is 163 MWe (Table 1). The field is located in the north-western part of the country and is an active hydrothermal area confined to a caldera-type collapse structure with a diameter of 15 km

The Miravalles Geothermal field is a typical high-temperature liquid-dominated reservoir. It is encountered at about 700 m depth, with reservoir temperatures declining towards the south and west (Vallejos, 1996). The production system used at present comprises mainly twenty-four production wells, (10 boreholes for Unit I, 8 for Unit II, 5 for Unit III and 1 for the back-pressure plant), seven steam separators (three separators for Unit I, three for Unit II and one for Unit III) and 10 injection wells, (7 for hot injection, 2 for cold injection and 1 that could be used for hot or cold injection according to the field operation needs) (Figure 2). Before being reinjected in the southern zone, the residual fluid first passes through the binary plant to generate around 15 MWe which decreases the temperature of the fluids from 165 to 135ºC.

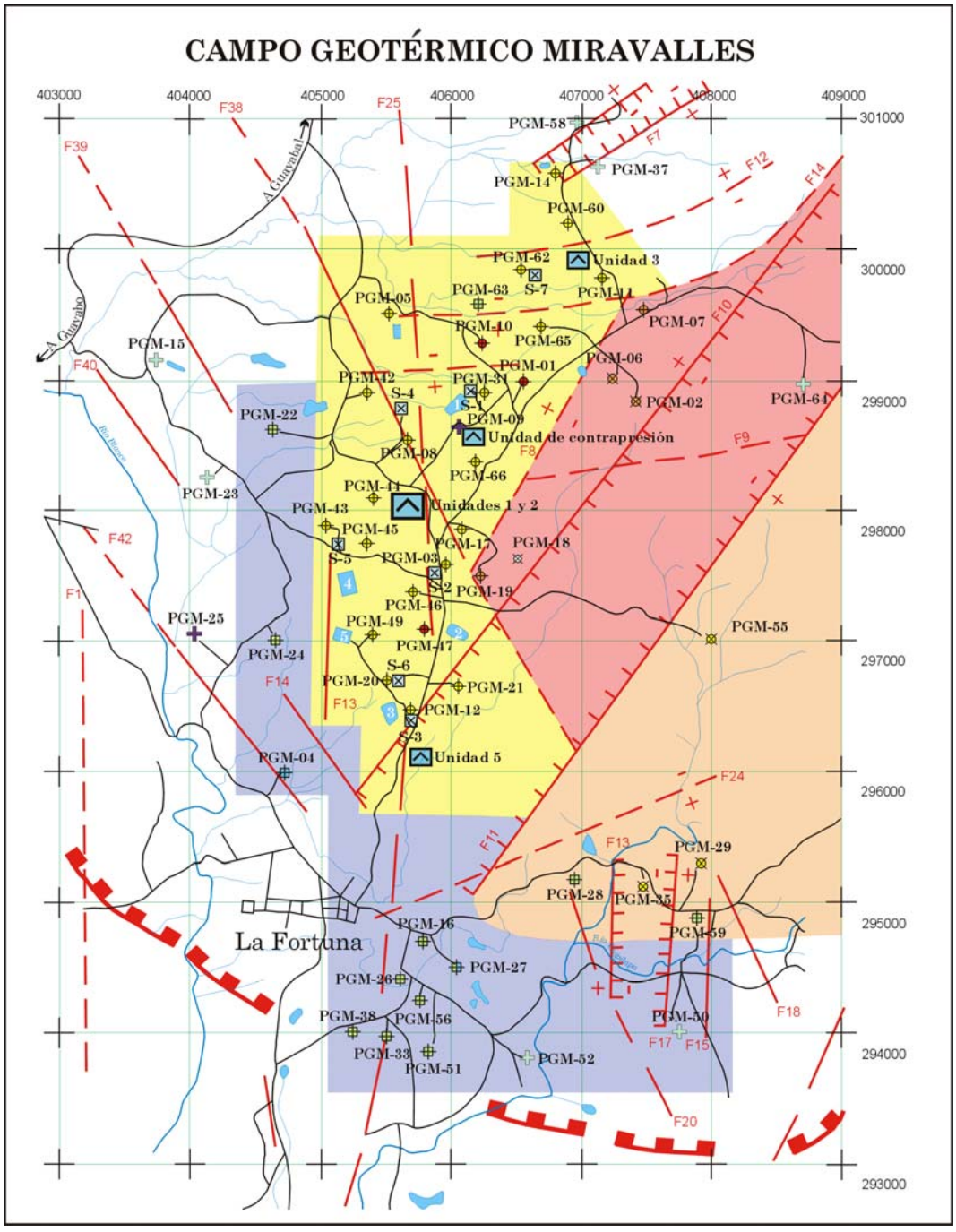

FIGURE 2: Miravalles geothermal field

Most of the fluids discharged by Miravalles wells are sodium chloride rich (78-80%), with TDS about 7000-8000 ppm, pH about 7-8, silica content around 550-650 ppm at atmospheric pressure and the non-condensable gas (NCG) content varies between 0.1 and 3.5%, weight of steam at 7 bar-a (neutral aquifer). Two more types of fluids are found in Miravalles: fluid with a pH around 2-4 and high sulphate concentration discharged by wells PGM-02, PGM-06, PGM-07 and PGM-19 (acidic aquifer); and a neutral fluid but with a high concentration of bicarbonate, an elevated NCG content (5-20%) and a lower Na^+/K^+ ratio than the neutral fluid, named the bicarbonate aquifer.

Most of the geothermal fluids coming from Miravalles wells form calcite scale (neutral and bicarbonate aquifers). The carbonate deposition occurs mainly in the flashing zone within the borehole, and it causes a decrease in flow rate and power generation. An inhibition system is used in Miravalles in order to avoid the calcite scaling. The scale inhibitor is pumped through small injection tubing and is dispersed below the boiling zone. The fluids coming from the acidic aquifer are neutralized by a solution of 50% sodium hydroxide, using a system similar to that of the inhibition system and at present they produce the steam for around 14 MW.

The wells located in the northern zone of the field are unique boreholes because they are not benefited by the reinjection waters. Therefore, the wells of this area are the most affected ones by the production rate and consequently the enthalpy, steam amount and NCG increase, whereas the flow rate and the head pressure decrease. Additionally, the reservoir drawdown rate is higher than expected.

2.2 Development phase

The only geothermal area in the development phase is the Las Pailas geothermal field. The area is located on the southern slope of the Rincón de la Vieja volcano, and a large part of the geothermal resource is within the Rincón de la Vieja National Park boundaries and the Guanacaste Dry Forest property. For this reason the study area is only around 11 km^2.

Here, five wells have been drilled during the first phase of ICE's feasibility project, three of them are production wells (PGP-01, PGP-03 and PGP-04), the fourth has low permeability and high temperature (PGP-02) and the fifth (PGP-05) has low permeability and temperature. The production rate of these wells varies from 7.7 to 20.9 kg/s and the enthalpy ranges from 971 to 1140 kJ/kg.

Most of the fluids discharged by the Las Pailas wells are sodium chloride type (83-84%) with TDS about 11500-12500 ppm, pH about 7-8, silica content around 600-720 ppm at atmospheric pressure and the non-condensable gas (NCG) content varying between 0.1 and 0.3% weight of steam at 6 bar-a separation pressure. Preliminary downhole measurements indicate temperatures close to 240°C.

At present, two wells (PGP-08 and PGP-09) are being drilled: PGP-08 for production and PGP-09 for reinjection (Figure 3). Also, groundwork is being done for the location of the power house, the separator station and other facilities.

2.3 Feasibility studies

At the present time, feasibility studies are being carried out in the Borinquen geothermal area (Figure 4). In this area geological and geochemical studies have been carried out. Two deep wells have been drilled in this area (PGB-01 and PGB-03). Well PGB-01 was drilled for production and it has the highest measured bottom-hole temperature in all of Costa Rica (275ºC). This well has a low production rate and initially had a low injection index which was modified by cold water injection in the permeable zone, increasing it from 1.4 to 7.2 l/s/bar. In the upcoming months a production test is being planned for this well.

On the other hand, PGB-03 is located in a low-permeability, low-temperature zone. Currently, two well pads are being prepared for drilling wells PGB-02 and PGB-06, and access roads are being constructed. Temperature gradient wells are being drilled and geophysical studies are being carried out in Borinquen.

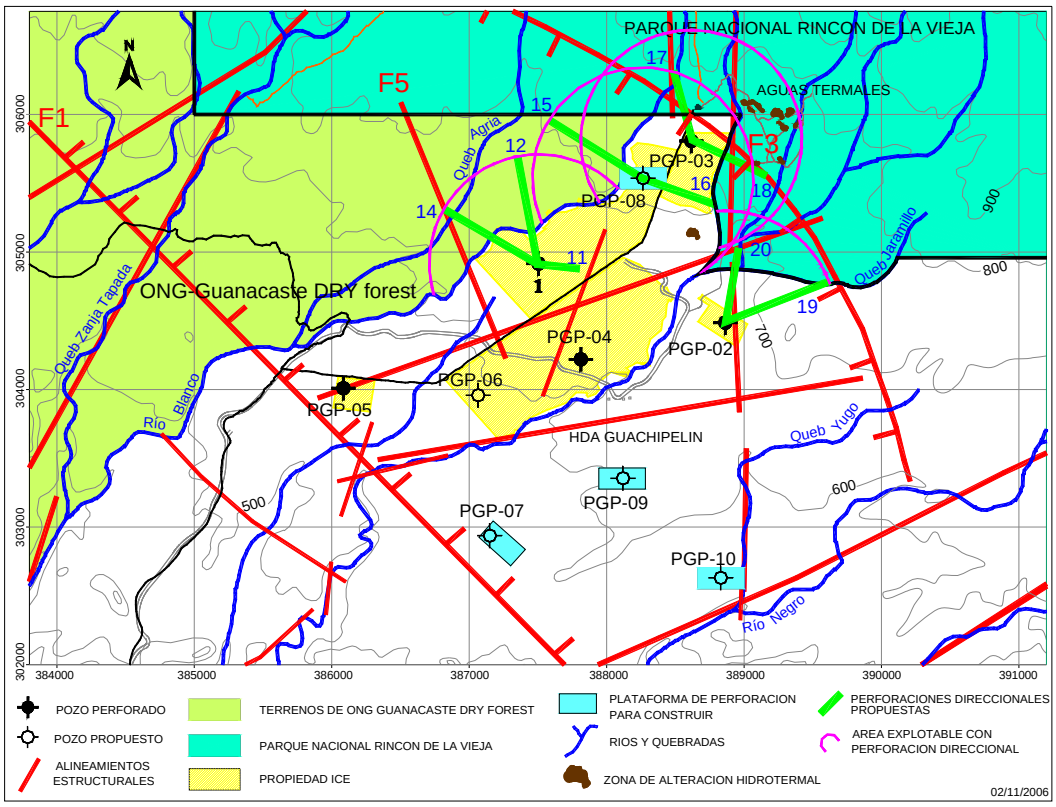

FIGURE 3: Pailas geothermal field

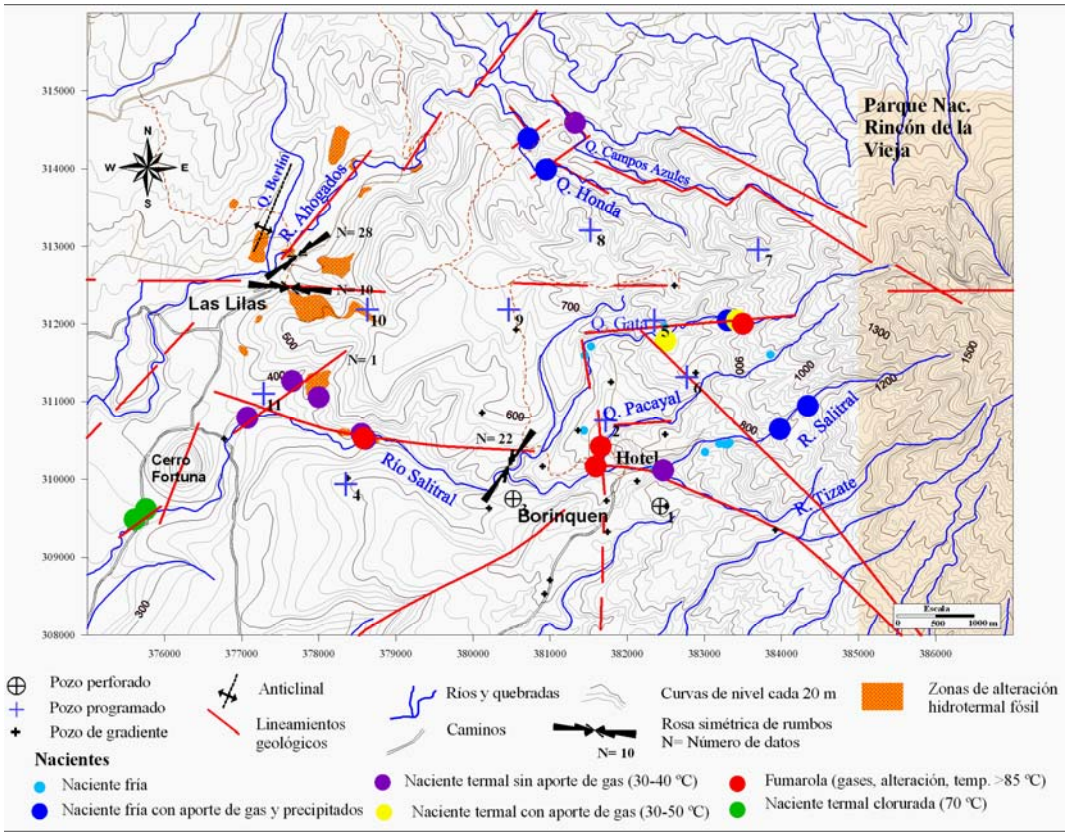

FIGURE 4: Borinquen geothermal area

2.4 Pre-feasibility studies

Tenorio geothermal area: A pre-feasibility study has already been concluded on the southern slope of the Tenorio volcano. Two exploratory wells were drilled at Tenorio (to 1,345 and 2,472 m depth) in 1999-2000. The results were disappointing, as they only encountered zones of low temperatures (less than 160 ºC) and low injectivity (less than 0.5 l/s/bar). According to this pre-feasibility study the resource is inside of the national park.

Mundo Nuevo geothermal area (Figure 5): Guanacaste Dry Forest is a non-governmental organization property located to the northwest of the Las Pailas geothermal field and has an extension of approximately 30 km^2. This property is administrated by Area de Conservación Guanacaste (MINAE), for which reason a special permit had to be confectioned in order to carry out exploratory studies in this area. Geological and geochemical studies were carried out in this area in 2007. Access roads to temperature gradient well sites are currently under construction and geophysical studies will be carried out in the upcoming year.

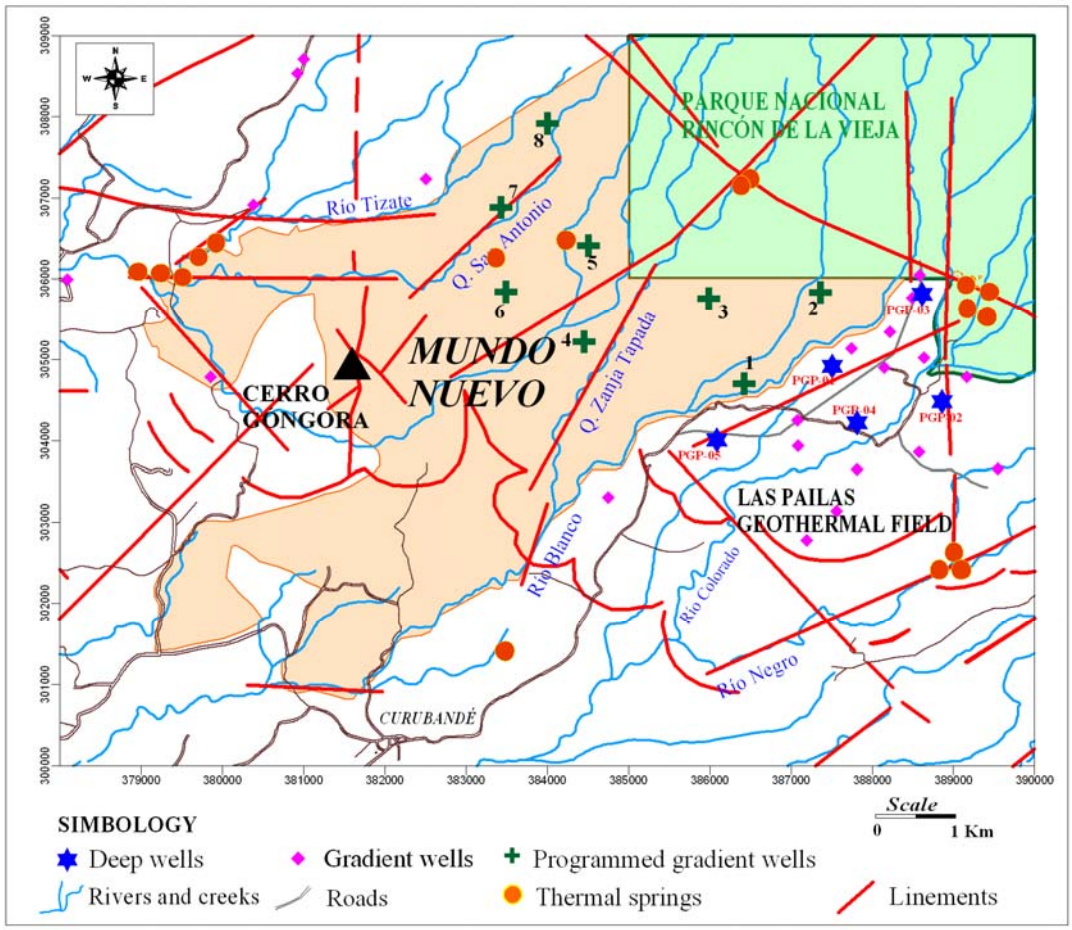

FIGURE 5: Mundo Nuevo geothermal area

2.5 Reconnaissance phase

Two areas are under reconnaissance studies: Pocosol and the northern zone of the Rincón de la Vieja volcano.

Pocosol: The Pocosol geothermal area is located to the south of the Arenal volcano, around 100 km northwest of the capital, San José. In this area geological and geochemical studies have been done in

the areas where permission has been granted. There is not a permission for exploration in the area known as "Bosque Eterno de los Niños" although it has been formally requested.

This area is located in Tertiary and Quaternary volcanic terrain, there are several hydrothermal manifestations like hydrothermal eruption craters, hot springs and hydrothermal alteration. The main geological structures are: the Peñas Blancas fault, the Javillos fault, the Pocosol caldera and los Criques Caldera. The Poco Sol area has favourable geological structures (the Pocosol caldera and associated faults) for the presence of a permeable geothermal reservoir and the Peñas Blancas and Jabillos neotectonic faults appear to control the movement of geothermal fluids and the presence of hydrothermal manifestations.

Most of the water samples are sodium chloride type which is interpreted as being representative of the geothermal reservoir discharge zone. The geothermometers applied to samples most representative of the geothermal reservoir indicate a temperature range from 183 to 217ºC.

Northern zone of the Rincón de la Vieja volcano: As the name indicates this zone is located in the northern part of the Rincón de la Vieja volcano. In this area geological and geochemical studies are being carried out at the present time. Thermal springs have been sampled with temperatures between 32 and 64ºC, and pH around 3.65 – 6.93. The acidic springs are located in the south of the area close to the active crater of Rincón de la Vieja while the neutral springs are located in north.

3. THE GEOTHERMAL ELECTRICITY GENERATION IN COSTA RICA

Most of the installed electricity generation capacity in Costa Rica comes from hydropower with smaller amounts from fossil fuel (bunker and diesel), geothermal and wind. The 2007 installed capacity of Costa Rica was 2182 MW, 68.8 % from hydropower, 19.4% from thermal (fossil fuel), 3.2% from wind and 7.59% from geothermal. On the other side, the generation of electricity for 2007 in Costa Rica was around 8,989 GWh 75.3% produced by hydropower, 8.2% by thermal (fossil fuel), 13.8% by geothermal, and 2.7% by wind, showing the good capacity factors of the geothermal plants.

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