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# A Status Report: Las Pailas Binary Geothermal Project Guanacaste, Costa Rica: A New Clean Renewable Energy Source for Costa Rica (Pre-Feasibility to Development Phases and Current Environmental Challenges)

Edward Charles Hakanson

Geologist, BSc., Instituto Costarricense de Electricidad  
La Fortuna de Bagaces, Guanacaste, Costa Rica  
[ECharles@ice.go.cr](mailto:ECharles@ice.go.cr)

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## ABSTRACT

The Las Pailas Geothermal Project is located on the Pacific slope of the Quaternary Rincón de la Vieja Volcanic Complex in Northwestern Costa Rica. It is the first geothermal project that the Costa Rican Electricity Company (ICE) will develop at Rincón de la Vieja and in Costa Rica and is preceded only by the 163.5 Mwe Miravalles Geothermal Project (also developed by ICE) located on the Pacific slope of the neighboring Miravalles Volcano, to the southeast. The Las Pailas Geothermal Project will provide clean renewable energy with a 35 MWe Binary Geothermal Plant which is projected to come on line in 2011 to partially fulfill the rising electricity demand in Costa Rica. Currently there are fourteen deep geothermal wells and nineteen temperature gradient wells drilled in the Las Pailas geothermal wellfield which encompassing a surface area of eight square kilometers, limited to the north by the Rincón de la Vieja National Park boundary and to the west by a private property called Mundo Nuevo which belongs to the Guanacaste Dry Forest Conservation Fund, a non-governmental organization. This paper addresses some of the geoscientific exploration activities during the Pre-Feasibility, Feasibility and Development Phases of the Las Pailas Geothermal Field, the consulting companies subcontracted during each of these phases, general local and well geology, and some of the environmental challenges that are currently being faced.

## Introduction

Clean renewable energy production is not new to Costa Rica. Hydro, wind, solar and even geothermal resources (at Miravalles Geothermal Field) have been exploited for a number of years. However, to mitigate the emissions of carbon dioxide to the atmosphere, the Costa Rican Electricity Company (ICE) has been developing more clean energy projects while at the same time

trying to reduce the use of fossil fuel plants. However, many of the renewable resources of energy depend on seasonal variations in the weather, limiting their energy production capability during certain periods of the year. This is not the case with geothermal power and that is why this form of energy production has become a very attractive option for complimentary energy production. The Las Pailas Geothermal Project is located in the Pailas Geothermal Field on the southern slope of the Quaternary Rincón de la Vieja volcanic complex in northwestern Costa Rica (Figure 1).

It is the first geothermal development at this volcano, preceded in Costa Rica only by the Miravalles Geothermal Project, located at the neighboring Miravalles Volcano to the southeast. The Pre-Feasibility studies at the Pailas Geothermal Field began in the 1970s with the first temperature gradient wells drilled in the area. Later, starting in late 1999, a deep well drilling campaign of five vertical wells (PGP-01, PGP-02, PGP-03, PGP-04 and PGP-05) with depths ranging from 1418 to 1827 meters as part

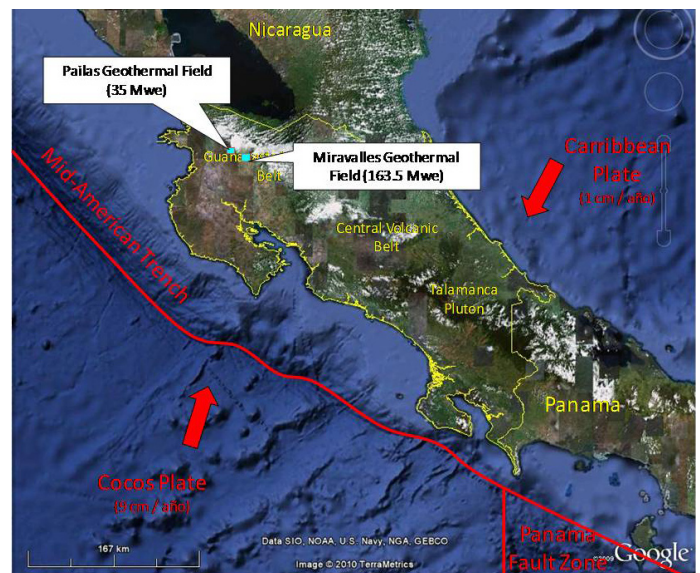


Figure 1. Location Map of the Pailas Geothermal Field in Northwestern Costa Rica.

of the feasibility study was carried out by the United States based companies Geothermex and Power Engineers (Moya 2010). The location of these wells can be seen in figure 5. The data from these first five deep wells, coupled with the data from the pre-existing 17 temperature gradient wells was used to create a geothermal model of the Pailas Geothermal Field. Later, a Japan based company, WestJEC, did another feasibility study utilizing the existing data at that time and finished with a final report in 2005. Although these two feasibility studies provide differing conceptual models of the Pailas Geothermal Field, they both agree that the field is capable of supporting a 35 MWe geothermal power plant. Backed by the prefeasibility and feasibility studies, the ICE conducted an Environmental Impact Study for the Las Pailas Geothermal Project, finishing also in 2005. At the present time there are a total of fourteen deep wells (nine vertical wells and five directionally drilled wells). The borehole stratigraphy has been correlated to the outcropping Pliocene to Pleistocene rocks and Holocene deposits in the field, however the deep units found in the boreholes do not crop out in the field area and may be Miocene in age.

A 35 MWe Pailas Geothermal Plant is currently under construction at the Pailas Geothermal Project and will provide an additional clean source of renewable power to the country, however it will also become a new point source of noise on the southern flank of the Rincón de la Vieja volcanic complex which by Costa Rican law shall not exceed a noise level of 75 dB-A in daytime or nighttime hours (Hakanson, 2010). The first ground movement for the Pailas Geothermal Project began in late 2007 and the plant is scheduled to be up and running in late 2011. The Pailas Geothermal field is bordered to the north by the Rincón de la Vieja National Park and to the west by a 2700 Ha non-governmental organization owned private property of protected land called Guanacaste Dry Forest Conservation Fund (Figure 3). Costa Rican law restricts the development of the Pailas Geothermal Field to the land outside the Rincón de la Vieja National Park border, reducing significantly the accessibility to the geothermal resources determined to be present on the southern face of the Rincón de la Vieja volcanic complex in the Pre-feasibility study (Moya, 2010). Furthermore, the non-governmentally owned private property of protected land to the west has only conceded limited access for ICE to do geothermal investigations at this west lying property, providing that both parties (the non-governmental organization and ICE) are in agreement and that the utilized areas be returned to their natural state once the exploration activities are done. This agreement has allowed for the construction of access roads and the drilling of some temperature gradient boreholes as well as geophysical studies (MT and gravity surveys) and geochemical studies of the surface waters. So far only two temperature gradient wells have been drilled at the Mundo Nuevo property, however, additional temperature gradient well drilling is forseen. Land use restrictions at the north bordering Rincón de la Vieja National Park and land use limitations in the west lying private protected property "Mundo Nuevo" have reduced the developable land area for the Pailas Geothermal Field to only eight square kilometers, approximately.

### Pre-Feasibility Study

The first temperature gradient wells drilled at the Pailas Geothermal Field were completed in the 1970s. To date there are 19

temperature gradient wells in the field. The two main objectives of these temperature gradient wells is to learn about the underlying geology and to construct a well sufficiently deep to be able to measure the anomalous heat source influenced temperature gradient of the zone. These wells range from about 50 meters depth to more than 600 m depth and according to Molina (2000) the temperature gradient increases towards the north-northeast (in the direction of the Rincón de la Vieja National Park).

### Feasibility Study

The feasibility study is marked mainly by the drilling of five deep geothermal boreholes during the period of late 1999 to 2002. It has been determined from this feasibility study that the most permeable zone is located in the central part of the field (wells PGP-01, PGP-04 and PGP-03) and that the hottest reservoir conditions are in this same sector and extending north-northeast of the deep well field. The feasibility study confirmed that there is an economically exploitable geothermal reservoir at the Pailas geothermal field sufficiently large to support a 35 MWe geothermal plant Geothermex (2005), WestJEC (2003) and therefore an Environmental Impact Study was done for the construction and operation of the Pailas Geothermal Plant. However, the problem of finding an adequate zone for the injection of geothermal brine continues to be a problem.

### Development

The development phase of the Las Pailas Geothermal Project was launched in 2008 with the drilling of additional deep boreholes in order to find an adequate zone for the injection of spent geothermal fluids. So far, in the development stage three vertical deep wells have been drilled in the southern part of the field to look for a permeable zone capable of receiving the geothermal brine from the 35 MWe geothermal plant without requiring the pumping of geothermal fluids to wells at higher elevations, however the vertical wells drilled during this period do not have an acceptable flow rate acceptance capacity. For this reason a directional drilling campaign began in 2009 to try to access permeable zones along faults, fractured rock layers and lateral discharge zones found in

**Table 1.** Deep geothermal boreholes drilled at the Pailas Geothermal Field up to May 2010.

Borehole	Start	Finish	TVD (m)	MD (m)	Azimuth
PGP-01	14-Nov-2001	15-Feb-2002	1418	1418	Vertical
PGP-02	30-Jun-2001	06-Oct-2001	1764	1764	Vertical
PGP-03	14-Jan-2001	11-May-2001	1772	1772	Vertical
PGP-04	19-Mar-2002	16-Jun-2002	1418	1418	Vertical
PGP-05	26-Jun-2002	21-Nov-2002	1827	1827	Vertical
PGP-06	06-Sep-2008	14-Abr-2009	1327	1327	Vertical
PGP-08	13-Jun-2008	11-Sep-2008	1712	1712	Vertical
PGP-09	11-May-2008	27-Jul-2008	1742	1742	Vertical
PGP-10	13-Dec-2008	25-May-2009	2673	2673	Vertical
PGP-12	03-Jul-2009	14-Oct-2009	1566.4	1694	NE
PGP-17	01-Nov-2009	En Proceso			NE
PGP-23	01-Nov-2009	25-Feb-2010	1853	2169.9	NNW
PGP-24	01-Jun-2009	14-Oct-2009	1381	1542	NE
PGP-25	16-Mar-2010	En Proceso			ESE

other deep wells in the field. At the present time, the entire well field covers approximately 8 sq km and has fourteen deep geothermal boreholes as given in Table 1.

**35 MWe Plant Construction**

The construction of the 35 MWe binary geothermal plant began in late 2007 with excavations and land moving activities in an area that covers approximately 13 Ha (Figure 2). A bidding process was done to select the contractor for designing the Las Pailas Geothermal Plant and the only offering company was ORMAT which is why this company was chosen for the contracting process. However all of the construction is done by the personnel from ICE (Moya, 2010). This 35 MWe plant will provide additional clean renewable energy to the national grid and is projected to be online in the year 2011 (Figure 3).

**Rincón de la Vieja National Park and Mundo Nuevo**

The Pailas Geothermal Field is bordered to the north by the Rincón de la Vieja National Park and to the west by the a private property of protected land called Mundo Nuevo which belongs to the Guanacaste Dry Forest Conservation Fund (Figure 2), a non-governmental organization. Current law in Costa Rica prohibits the exploration and development of geothermal resources located within National Park boundaries. Furthermore in the west lying Mundo Nuevo property, only limited access has been given for temperature gradient well drilling and access road construction. Aside from the access road construction, the only exploration drilling in the area was done at two temperature gradient wells (PP-19 and PP-20) in the year 2009.



Figure 3. Recent photo mosaic of the advance of construction the Pailas Geothermal Plant (March 3, 2010).

**Surface Geology**

For the surface geology of the Pailas Geothermal Field, the Geologic Map published in Chavarría, et al. 2010 is used and shown in Figure 4. On this map there are five main geologic units: (1) Surficial Rocks Unit; (2) Formación Pital; (3) Formación Liberia; (4) Domes Unit; and (5) Bagaces Group.

From the most recent to the oldest there are:

**Bagaces Group:** Formed by four units including pumiceous to blocky pyroclastic flows, dacitic lavas and ignimbrites associated with the Cañas Dulces Caldera border (Alcántaro Formation) and hipabissal andesite composition dykes found locally in rivers near the caldera border.

**Liberia Formation:** Widespread rhyolitic biotite and quartz bearing pumiceous tuff in a white ashy matrix. The age of this unit has been dated as 1.6 my. Lithic horizons are common, containing mostly porphyritic andesite clasts although granitoid clasts can be found locally in the basal section this tuff (Hakanson, 2010).

**Domes Unit:** Group of dacitic to rhyodacitic domes that rise above the surrounding topography approximately 100 – 300 meters and which may be the result of a terminal extrusive phase following the eruption of the Liberia Tuff. The dome field is

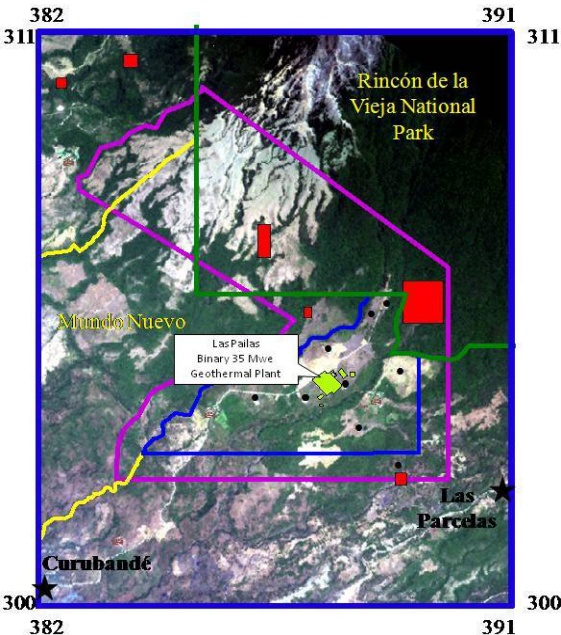


Figure 2. Location map of the Pailas Geothermal Field showing the borehole field (black dots), the location of the 35 MWe geothermal plant currently under construction (green box) and the bordering properties Rincón de la Vieja National Park and Mundo Nuevo.

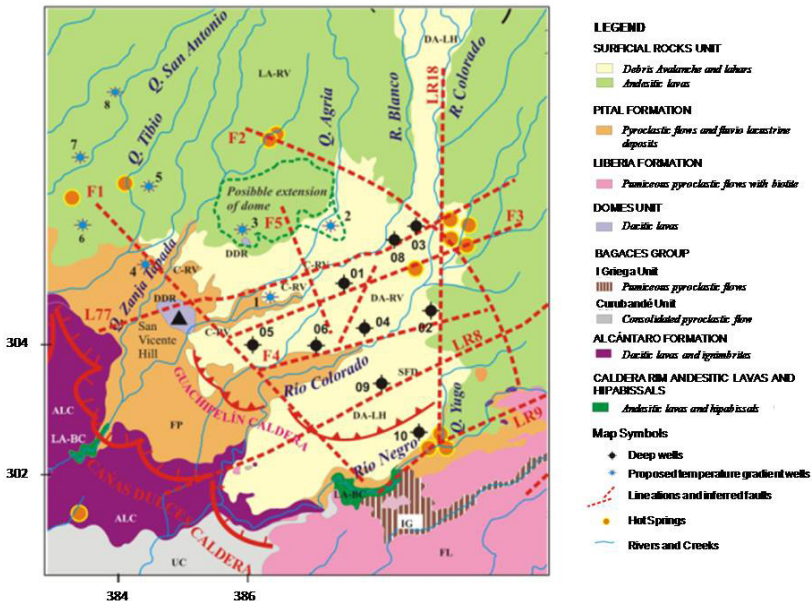


Figure 4. Geologic map of the Pailas Geothermal Field (Chavarría et al. 2010).

located to the west of the Pailas Geothermal Field and covers approximately 10 km<sup>2</sup>.

**Pital Formation:** Pumiceous pyroclastic flows with few to no lithic horizons and very low crystal content. Intercalated with these pyroclastic flows lacustrine deposits can be found locally. This formation is located mostly within the Cañas Dulces Caldera.

**Surficial Rocks Unit:** This unit includes recent andesitic lava flows from the southern slope of the Rincón de la Vieja Volcanic Complex as well as a lahar – debris avalanche flow that collapsed from high up on the southern flank of the Rincón de la Vieja Volcanic complex and may be attributed with a large breached caldera rim.

**Borehole Geology**

In the deep Wells six informal Quaternary geologic units have been identified (Figure 5), all of which have been correlated with the outcropping geology, with the exception of the deepest units (Lower Bagaces Group and Aguacate Group). The general down-hole volcanostratigraphic rock sequence in the wells is:

**Recent Products from Rincón de la Vieja volcano:** Mostly lahar and debris avalanche deposits associated with Holocene activity at the southern slope of the Rincón de la Vieja volcanic complex.

**Pital Formation:** Late Pleistocene sequence of pumiceous, crystalline and cristal-lithic pyroclastic flows embedded in white to beige ashy matrix. Also in this formation sporadic lacustrine deposits are found.

**Dome Unit:** Late Pleistocene dacitic to rhyodacitic lavas that are associated with an intracalderic dome field located to the west of the Pailas Geothermal Field.

**Biotite Flow:** Pleistocene rhyolitic pumiceous cristaline pyroclastic flow containing white pumice and characteristic primary quartz and biotite crystals in a white ashy matrix. Also found in this unit are sporadic lithic fragments which are mostly andesitic in composition.

**Bagaces Group:** Plio-Pleistocene sequence of dacitic to andesitic tuffs containing intercalated lava flows and ignimbrites. The Cañas Dulces Caldera Border is formed by the Alcántaro Formation which belongs to this rock group and crops out in an arcuate form at the southwestern part of the field area. The Alcántaro Formation is the oldest outcropping rock unit at the Pailas Geothermal Field.

**Aguacate Group:** Primarily andesitic lava flows, possibly Miocene in age, with intercalated cristaline lithic tuffs and volcanic brechas that do not crop out at the Pailas Geothermal Field. This unit may be contemporaneous with the Miocene Aguacate Formation located elsewhere in Costa Rica.

SMU	Surficial Materials unit
PF	Pital Formation
DU	Dome Unit
LF	Liberia Formation
BG	Bagaces Group
AG	Aguacate Group

*(Not to Scale)*

**Figure 5.** Generalized downhole lithologic sequence at the Pailas Geothermal Borehole Field.

**Conclusions**

To mitigate the emissions of carbon dioxide to the atmosphere, the Costa Rican Electricity Company (ICE) has been developing more clean energy projects while at the same time trying to reduce the use of fossil fuel plants.

The Las Pailas Geothermal Project, located at the southern slope of the Quaternary Rincón de la Vieja Volcanic Complex in Northwestern Costa Rica is expected to provide 35 MWe of additional clean renewable energy to Costa Rica starting in late 2011.

The prefeasibility and feasibility studies for the Pailas Geothermal Project as well as an Environmental Impact Study had been completed by 2005 and at the present time the Pailas Geothermal Project is in the Development stage.

The north bordering Rincón de la Vieja National Park and the west bordering privately owned protected land Mundo Nuevo limit the possibilities of future exploration and development of the Pailas geothermal field in these areas.

Surface geology and borehole geology have been correlated well. The deepest units in the boreholes do not crop out at or even near the Pailas Geothermal field. Based on local surface geology, the oldest rocks in the borehole field (Aguacate Group) may be Miocene in age.

At the the present time sufficient steam has been found to start up operation of the 35 MWe plant at Las Pailas Binary Geothermal Project, however more boreholes need to be drilled to compliment the necessary injection capacity for the spent brine from the plant.

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