Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Direct Subsoil Temperature Measurements at and around the Las Pailas Geothermal Project and in Rincón de la Vieja National Park, Guanacaste, Costa Rica

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Keywords: Direct soil temperature measurements, Las Pailas Geothermal Project, Rincón de la Vieja National Park, Guanacaste, Costa Rica

ABSTRACT

Direct soil temperature measurements have been made in access holes drilled down to a maximum of 160 cm in the area that will be directly impacted by the operation of the Las Pailas Geothermal Project, as well as within the north bordering Rincón de la Vieja National Park. Each access hole is one kilometer apart and the temperature has been measured periodically at each one since June, 2008. Throughout the field area there are important differences in soil type, geological formations, elevation, and geothermal activity, all of which may influence the measured subsoil temperatures. Additionally, a soil temperature gradient was determined for each access hole by taking temperature measurements at 5, 10, 20, 50, 100 and 150 cm depth in an unlined hole. All of these data have been compiled in an Access database and integrated so that they can be visualilzed in ArcView.

This report presents the findings of this investigation thusfar and conclusions which may, along with future results, be utilized in the decision making process for future development of the Las Pailas Geothermal Field.

1. INTRODUCTION

Beginning in late June of 2008 and as part of a field investigation for a Master's Thesis in Natural Resource Management, in a field area with an extension of approximately 3200 Hectares (32 km2) located within the Costa Rica Lambert North coordinates 300-311 N, 382-391 E (Curubandé topographic base map, 1:50000) on the Pacifica slope of Rincón de la Vieja Volcano in Guanacaste, Costa Rica (Figure 1), direct temperature measurements have been made periodically at 57 access holes manually augered to an approximate depth of 150 cm in order to obtain the first subsoil temperature data collected on a 1 km grid in the area to determine if on this scale high temperature subsoil anomalies produced by a near surface or deep heat source can be detected by measuring subsoil temperatures at shallow depth and filtering out the effect of the annual temperature wave. In 2007, Eneva et al carried out a similar field study at Coso Geothermal Field but on a much smaller scale and around known thermal manifestations. The field study presented in this paper is separated in two phases: 1) field location, access hole preparation and site description; and 2) periodic temperature measurements at each of the 57 access holes. The field area is concentrated at and around the under development Las Pailas Geothermal Project (Instituto Costarricense de Electricidad, 2005) totaling an area of the area of 1312 Ha, the southwestern corner of Rincón de la Vieja National Park (1189 Ha) and extends towards the northwest covering 788 Ha along a possible regional northwest trending fracture system associated with thermal manifestations. The entire field area is of geothermal interest that may be explored in the future in a drilling campaign as part of a feasibility study. In this investigation, bottom hole subsoil temperature measurements are made approximately once every four months. This investigation does not account for surface albedo although differences in elevation, soil type, underlying geology and geothermal activity are considered.

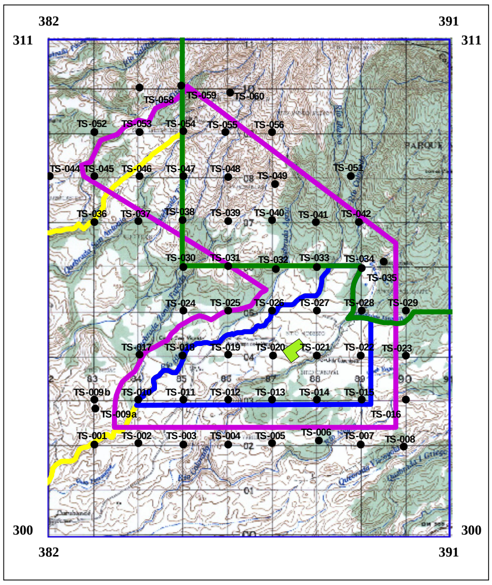

Figure 1: Field Area. The purple line encloses the area under study; the blue line is the area currently under development at the Las Pailas Geothermal Project; the green line is the border of Rincón de la Vieja National Park and the yellow line is the border of Mundo Nuevo, a private property owned by Guanacaste Dry Forest (a non governmental organization) and administered by the Costa Rican Park Service. Access hole locations are marked with a black dot and the green polygon represents the location of the future 35 Mw power plant of the Las Pailas Geothermal Project

On the 1:400000 Geological Map of Costa Rica (Denyer and Alvarado, 2007) seven geological units are observed from the Late Miocene (southwestern corner of the field area) to the Pleistocene (Northern part of the field area) all of which are igneous (Figure 3). It is evident that recent pliestocene volcanic material was deposited over the older Early Pliocene and Miocene tuffs.

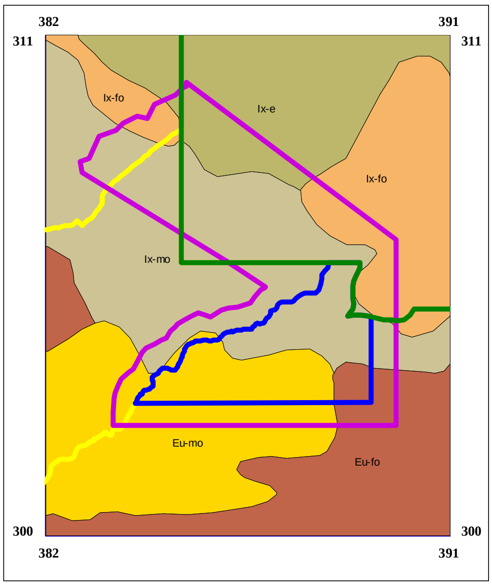

Figure 2: Soil map of the field area (Digital Costa Rica Atlas, 2008). Yellow and Brown: Entisols; Gray Orange and Kaki Green: Inceptisols

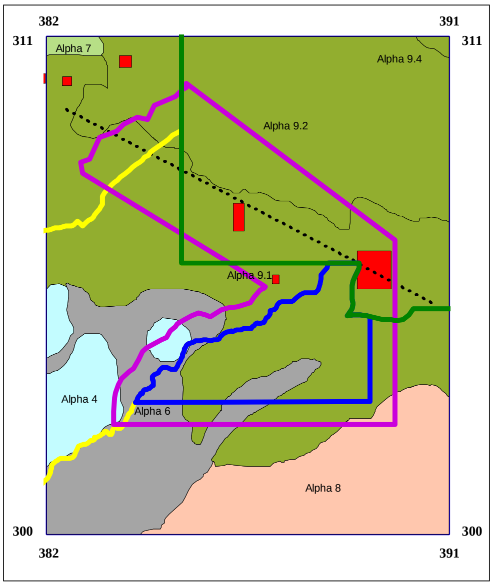

Figure 3: Geologic map of the field area (after Denyer and Alvarado, 2007). Gray: Miocene Bagaces Formation; Cyan: Early to late Pliocene Cañas Dulces Dome Unit; Light Green: Late Pliocene Monteverde Formation; Pink: Early Pleistocene Liberia Formation; Dark Green: Recent Pleistocene volcanic products; and Red: Thermal manifestations (taken from Chavarría et al, 2006). The black discontinuous line represents a possible northwest trending fracture system associated with the thermal manifestations and observed in Denyer and Alvarado, 2007

2. FIELD LOCATION, ACCESS HOLE PREPARATION AND SITE DESCRIPTION

After marking the field area on the 1:50000 Curubandé topographic base map, field work began in late December of 2007 with the field location of 57 observation points on a 1 km grid distributed between 422 and 1291 m s.n.m. (Figure 1). At each of observation point a 36 inch Oakfield Auger/Tube Kit with a 30 inch extension rod was used to drill a 3 cm access hole to 150 cm or as deep as the subsoil would permit. Each access hole was immediately lined with an open 1” PVC tube to the bottom of the hole and capped at the surface to prevent anything from falling into and obstructing the access hole. During this first phase of the field campaign (12/07-06/08) field data were also taken at each observation point on: the soil type, and outcropping geology. Using the Curubandé topographic base map, the field was divided into fourteen field sectors (Figure 4).

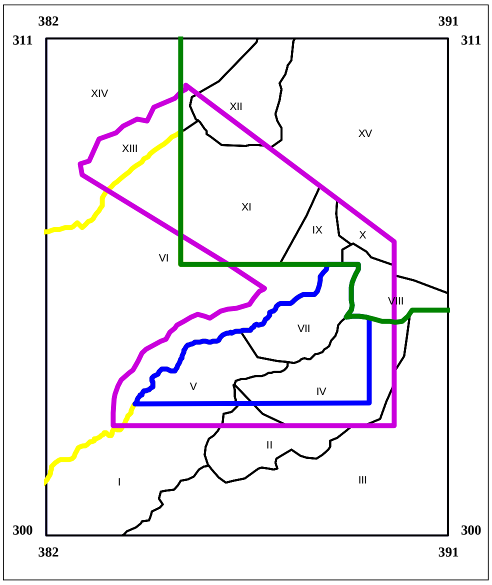

Figure 4: Field Sectors. I (Sector Guachipelín); II (Sitio Varialles); III (Las Parcelas de Santa María); IV (Sitio Cabuyal); V (Hacienda Guachipelín); VI (Mundo Nuevo); VII (Sitio Modesto); VIII (Sitio Coyol Guape); IX (Sitio Pará); X (Sitio Balsa); XI (Sitio Las Hornillas); XII (Sitio Ojos de Agua); XIII (Sitio Salsipuedes); XIV (Borinquen); XV (Parque Nacional Rincón de la Vieja

2.1 Sector Guachipelín (I)

Three access holes were augered to depths of 47 to 123 cm in clay rich to silty soil with millimetric lithic fragments from underlying dacite lava, locally.

2.2 Sitio Varillales (II)

Three access holes were augered to depths of 150 to 167 cm in the black silty loam of a lahar deposit and gray silty soil developed on a gray volcanic brecha.

2.3 Las Parcelas de Santa María (III)

Three access holes were augered to depths of 146 to 167 cm in white pumice tuff with poor soil development, a dark brown clay rich silty avalanche deposit over white pumice tuff and in place non-cohesive whitish gray mineral soil developed from a white pumice rich lithic tuff with a characteristic biotite and embayed quartz rich matrix.

2.4 Sitio Cabuyal (IV)

Six access holes were augered to depths from 146 to 167 cm in loamy brown to clay rich light brown soil, and black clay-rich soil formed over a brown clay-rich loam.

2.5 Hacienda Guachipelín (V)

Three access holes were augered to a depths from 89 to 157 cm in white pumice tuff with poor soil development, brownish sandy loam developed over a white biotite bearing tuff and a brownish gray silty soil developed over a pyroclastic flow sequence.

2.6 Mundo Nuevo (VI)

Ten access holes were augered to depths from 23 to 165.5 cm in well developed light brown silty soil, brown silty loam, light brownish gray soil to black loamy soil developed over a yellowish to orange tuff locally, and an ash-rich silty gray soil with sporadic milimetric fragments of altered lava.

2.7 Sitio Modesto (VII)

Two access holes were augered to depths of 64 to 90 cm in light brown silty loam and black soil, both of which are associated with the matrix of a recent lahar deposit.

2.8 Sitio Coyol Guape (VIII)

Five access holes were augered to depths of 42 to 160 cm in brown silty clay loam, dark brown silty loam, black soil, brown loam and hydrothermally altered clay-rich soil which have developed over a recent lahar deposit locally and over recent andesitic lava flows, elsewhere.

2.9 Sitio Pará (IX)

One access hole hole was augered to a depth of 42 cm in a poorly consolidated dry brown silty loam, which forms the matrix of a recent lahar deposit.

2.10 Sitio Balsa (X)

Two access holes were augered to depths of 85 to 127 cm in alluvium and a colluvium composed of black soil containing large andesitic blocks.

2.11 Sitio Las Hornillas (XI)

Nine access holes were augered to depths of 50 to 165 cm in gray to tannish brown silty volcanic ash-rich soil, dark brown soil, black loamy locally clay-rich soil, and light brown clay-rich soil.

2.12 Sitio Ojos de Agua (XII)

Three access holes are augered to depths of 144 to 160 cm in light brown loamy to clay-rich soil, locally capped by a layer up to 70 cm of a yellow pumice fall deposit.

2.13 Sitio Salsipuedes (XIII)

Three access holes are augered to depths of 150 to 162 cm in a silty tan to gray volcanic ash-rich loam over a thin (</= 5 cm) near-surface pumice deposit.

2.14 Borinquen (XIV)

Four access holes are augered to depths of 112 to 166 cm in a light brown to gray silty volcanic ash-rich soil, locally underlain by yellow pumice.

3. RESULTS FROM PERIODIC SUBSOIL TEMPERATURE MEASUREMENTS

Subsoil temperature data collection began in late June 2008 and to date, three subsoil temperature suverys (Table 1) have been made at all fifty-seven access holes in the field area (171 subsoil temperature measurements). Temperature was measured using a three-meter long Type T thermocouple with a 15 cm teflon lined probe and an EXTECH Easy View 15 Digital Thermometer Datalogger.

Table 1. Subsoil Temperature Surveys.

Survey	Dates
1	06/20/2008 – 11/27/2008
2	10/11/2008 – 03/06/2009
3	03/03/2009 – 05/30/2009

Subsoil temperature values ranged from 13.7 to 95.5 ºC and were entered into an Access Database. The highest value was taken in an active fumarole and the lowest corresponds to a temperature measurement taken at 1262 m s.n.m. (Table 2, Figure 5). Setting aside the temperature measurement obtained at the fumarole, the highest temperatures are registered at access holes TS-001, TS-002, TS-004 and TS-011 in all three surveys.

Table 2. Access Holes and Temperature Ranges Measured at the Fourteen Field Sectors.

Sector	Access Holes	Temperature Range
Sector Guachipelín	001, 002, 003	23.6-29.3
Sitio Varillales	004, 005, 006º	18.8 (22.8)*-28.7
Las Parcelas de Santa María	007, 008, 016	16.5 (23.2)*-26.2
Sitio Cabuyal	013, 014, 015, 021, 022, 023	24.8-27.3
Hacienda Guachipelín	011, 012, 019	22.3-27.2
Mundo Nuevo	009, 010, 017, 018, 024, 025, 026, 036, 037, 046	17.3 (20.3)*-27.7
Sitio Modesto	020, 027	23.4-26.3
Sitio Coyol Guape	028, 029, 034, 035, 041	20.3-23.9; 91.3-95.5**
Sitio Pará	033	19.4-22.3
Sitio Balsa	042, 051	19.1-21.5
Sitio Las Hornillas	030, 031, 032, 038, 039, 040, 047, 048, 049	14.7 (22.4)*-27.2
Sitio Ojos de Agua	055, 056, 060	13.7 (19.3)*-23.8
Sitio Salsipuedes	045, 053, 054	21.5-24.7
Borinquen	044, 052, 058, 059	15.2 (21.4)*-27.2

*Some values from the second survey are below 19.3 ºC and considered anomalously low. Therefore, these may not coincide with the regional annual temperature wave.

**These values are influenced by a near-surface heat source that produces an active fumarole at TS-034.

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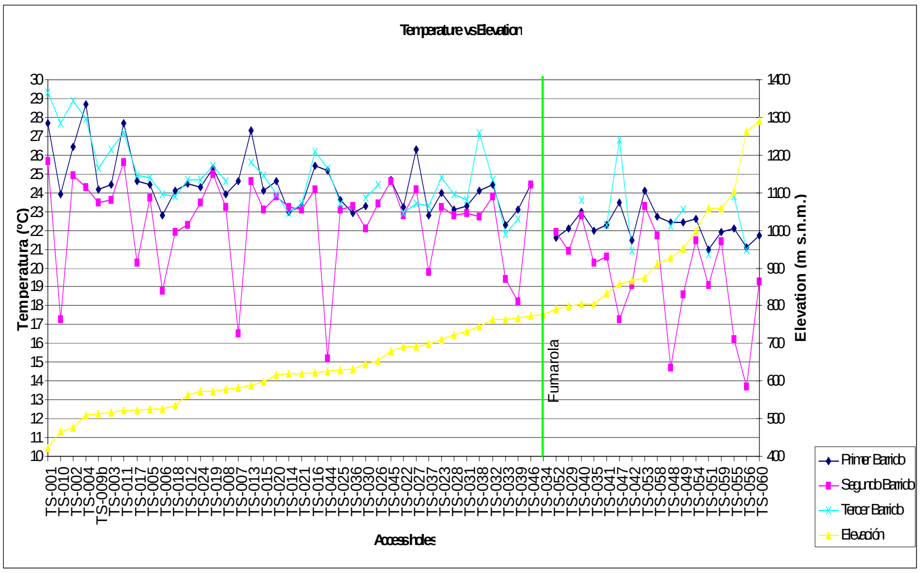

Figure 5: Subsoil temperature values (blue, magenta and cyan lines correspond to the first, second and third surveys respectively). Access points are arranged in order of increasing elevation (yellow line). The vertical green line represents TS-034 where the subsoil temperature is 91.3 to 95.5 ºC

The subsoil temperature has a small spatial variation throughout the year, which indicates that the annual temperature wave in the subsoil has rather low amplitude. The low temperatures corresponding to the second round of subsoil temperature measurements largely follow the same pattern as the first and third surveys. This suggests that during these readings the datalogger may have been poorly calibrated and these data must be corrected. However, subsoil temperatures tend to decrease with topographic elevation. Exceptions to this are: TS-016 in Las Parcelas de Santa María, TS-027 in Sitio Modesto, TS-038 in Sitio Hornillas, TS-044 and TS-053 in Borinquen and TS-046 in Mundo Nuevo, where relatively high temperatures were registered, regardless of elevation.

CONCLUSIONS

Soil types sampled in this field study correspond well with the Soils Map in the Digital Costa Rica Atlas 2008 and the outcrops observed in the field on a 1 km grid coincide with the Geological Map of Costa Rica at a 1:400000 scale. Subsoil temperatures taken at a minimum depth of 50 cm seem to be sufficiently representative and can be used to filter out the annual temperature wave because the downhole temperatures from 50 cm to 150 cm vary less than 1 ºC in this field, if there is not a near-surface heat source such as at TS-034. The subsoil temperatures measured at and around the Las Pailas Geothermal Field have a small annual and spatial variation (3-6 ºC). Regardless, it is evident that the sectors with higher subsoil temperatures are located in: Sector Guachipelín, Sitio Varialles, Sitio Cabuyal, Hacienda Guachipelín, Mundo Nuevo, Sitio Las Hornillas and Borinquen (setting aside the anomalously high subsoil temperatures at TS-034, obtained at an active fumarole in Sitio Coyol Guape). Nonetheless, Sector Guachipelín, Sitio Variallales, Sitio Cabuyal, and Hacienda Guachipelín are at lower elevations and are more distant from the Rincón de la Vieja volcanic complex; are underlain by older geologic units and are covered by a poorly developed soil. On the other hand Mundo Nuevo, Sitio Las Hornillas and Borinquen are at higher elevation and closer to the volcanic edifice; are underlain by younger geologic units and are covered by better-developed soils. Taking into consideration that geothermal power in Costa Rica is closely related with volcanoes these last three regions may be a positive geothermal prospect. The scale at which subsoil temperature data is collected is directly related with the potential for a meaningful interpretation of the data. A one kilometer grid seems to be sufficient for this type of large-scale study to identify soils potentially heated by deep or near-surface heat sources and may be used in low impact low cost geothermal prospection studies. Although in order to determine the orientation of a heat source or a fracture system, it is recommended to collect data at a much smaller scale (100 m grid), and in a reduced field area. Albedo was not taken to account in this investigation because the subsoil temperature measurements were sufficiently deep to not be affected by the diurnal temperature wave although it should be considered for subsoil temperature surveys at shallower depths, especially when studying the effect of the diurnal temperature wave on soil temperature changes.

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