Study on diffuse degassing and alteration mineralogy in the Berlín Geothermal Field

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Abstract

Due to its recent geothermal development in El Salvador, various monitoring activities are periodically undertaken in Berlín geothermal field to provide more data and information for the construction of the conceptual model of the field and to give an idea of the chemical, physical and thermodynamic behavior of the field. Among these activities are the study of diffuse degassing and the periodic monitoring of fumaroles. Radon and thoron contents show anomalies at the northeastern part of Alegría City, which could be a possible area for investigation. The study of gases and alteration mineralogy is very much related. The type of hydrothermal minerals also depends on the permeability and chemical content whether it is gas or liquid. High and high gas anomaly mainly CO_2 are observed in the central part of the field mainly in Tronador y Tronadorcito fumaroles. Alteration and gas studies confirm the upflow zone of the field. Almost all of the fumaroles are related with geologic structures, which provided passage for hydrothermal fluids to reach the surface. Likewise, most of the gas anomalies are located in fault zones.

***Key words**: diffuse degassing, alteration mineralogy, conceptual model, Berlín field.*

1 Introduction

Due to its recent geothermal development in El Salvador, various monitoring activities are periodically undertaken in Berlín geothermal field to provide more data and information for the construction of the conceptual model of the field and to give an idea of the chemical, physical and thermodynamic behavior of the field. Among these activities are the study of diffuse degassing and the periodic monitoring of fumaroles.

This paper includes the results of the study of gases mostly CO_2, radon and thoron relating gas anomalies with permeable zones and movement of fluids while the monitoring of fumaroles suggests the variation in area and type of alteration and the prediction and prevention of geologic hazards that may occur (i.e. hydrothermal eruption).

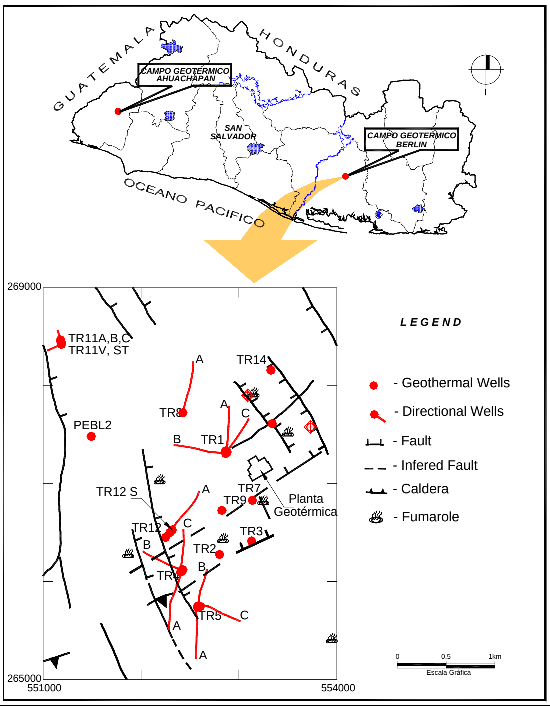
The study area comprises a total area of 29 km^2 and part of the southeastern part of the field. It is worthwhile mentioning that the study of diffuse degassing was carried out for the first time in December 2000 before the strong earthquake in January 13, 2001, which devastated a lot of properties.

2 General description of Berlin

Berlín geothermal field is located at the eastern part of El Salvador in Central America (Figure 1), 100 km. east of San Salvador city, the capital of El Salvador. It lies at the northern slope of the Berlín-Tecapa volcanic complex and has an area of about 24 km^2 with an estimated geothermal power potential of 85 MWe.

In 1992, a backpressure unit was commissioned using well TR-2 as a production well and wells TR-1 and TR-9 as reinjection wells. Expansion of the geothermal field was a priority to address the growing demand of electrical energy of the country.

To date, 31 wells have been drilled in Berlín with a total number of 10 wells used for producing an installed capacity of 56 MWe, two units of 27.5 MWe from a single flash condensing power plant, 11 reinjection wells and the rest as exploratory wells and/or without commercial use (Artola, S. pers.com. 2002).



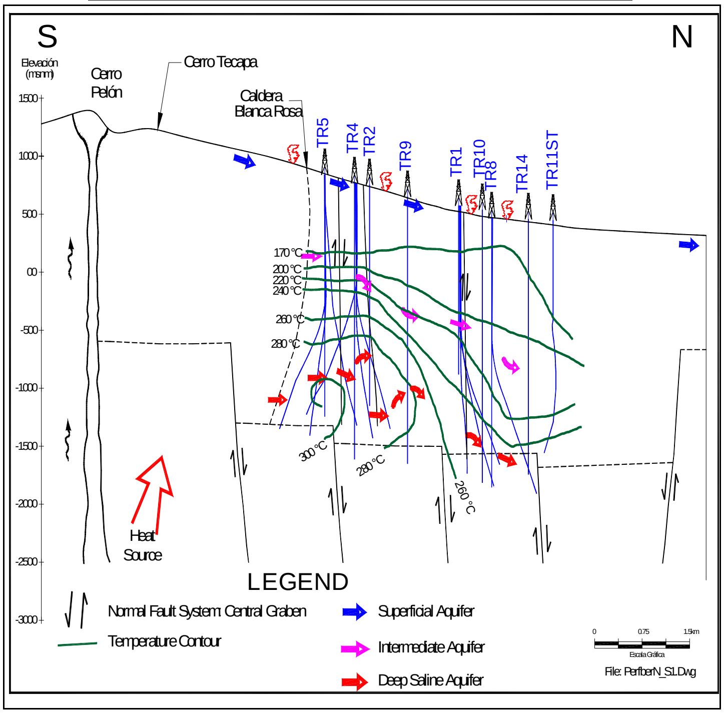


Figure 1: Location map of Berlín Geothermal Field.

Figure 2: Conceptual Model of the Berlin Geothermal Field.

Based on the geoscientific studies, the upflow zone is located beneath the Berlín-Tecapa volcanic complex, at the southern part of the field near where TR-5 wells are situated. Hydrothermal fluids flow laterally along the circular faults of the Blanca Rosa and Berlín calderas in a north-northwest direction (Barrios et al, 2001). Measured reservoir temperature is 305°C while calculated temperature based on different geothermometers is 350°C. The outflow zone is assumed to be at the northern part of the area. See Figure 2.

3 Results of study

A. Diffuse degassing

Radon gases in soils and fumaroles are used to identify convective flow areas and to monitor degassing changes through time. ^{222}Rn (t½ = 3.8 days), ^{220}Rn (t½ = 55 sec) and ^{219}Rn (t½ = 3 sec) form the isotopic group which decay from radioactive natural elements such as ^{235}U and ^{238}Th ^{222}Rn are soluble in water and its solubility increases with decreasing temperature (Mania et al., 1995). Due to the half-life of radon, in areas where slow diffusive flow exists, the average depth of origin is approximately 2 m (Connor et al, 1996). Therefore the high concentrations of radon are more likely to be due to convective movement of gases rather than diffusive processes.

Thoron gas (^{220}Rn) disintegrates rapidly and is present only a few minutes after the collection of sample. Its half-life is 55 sec (Hutter, 1995), and it is difficult to obtain an exact quantitative measurement of its concentration.

High fluxes of hydrothermal gases are usually discharged at the end of the faults or where multiple faults intercept (Chiodinni, G., et al, 1994). CO_2 gas is the most abundant gas after water vapor, hence it is considered very useful to monitor volcanic changes, magma movements and usually related to permeable zones in volcanic geothermal fields.

Results of radon survey are shown in Figure 3 where anomalies are observed in: a) an inferred fault (based on geophysical survey) parallel to Guallinac Fault at the eastern part of the field, b) northern part of the fumarole in Vuelta de San Juan and c) northeastern part of Alegria City along the inferred faults (based on geological studies), which are seen at the southeastern part of the field.

Anomalies of thoron content as observed in Figure 4 show almost the same areas observed in radon survey and in Caserio La Corriente at the northern part of San Juan fault and coincide with the present alteration in the area.

In Figure 5, the presence of CO_2 anomalies are well observed along the area of Guallinac Fault and the inferred fault west of this fault which indicates areas of high emanation of CO_2 along a permeable zone where ascent of magmatic fluids are present. This coincides with the upflow zone located at the Berlín-Tecapa volcanic complex.

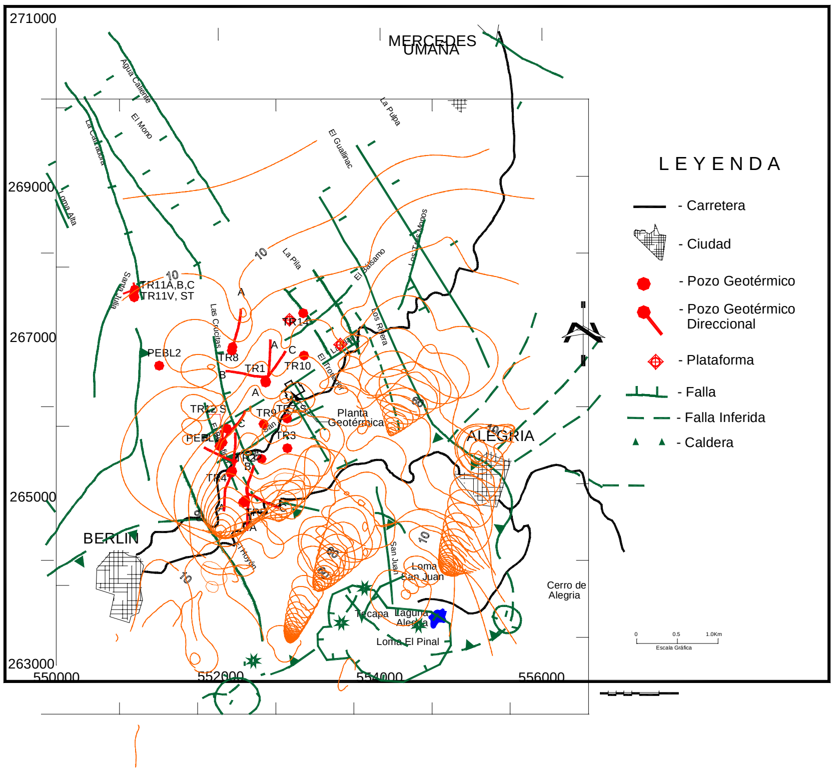


Figure 3: Results of radon survey at southeast area of Berlin Geothermal Field (0-300 pCurio/L).

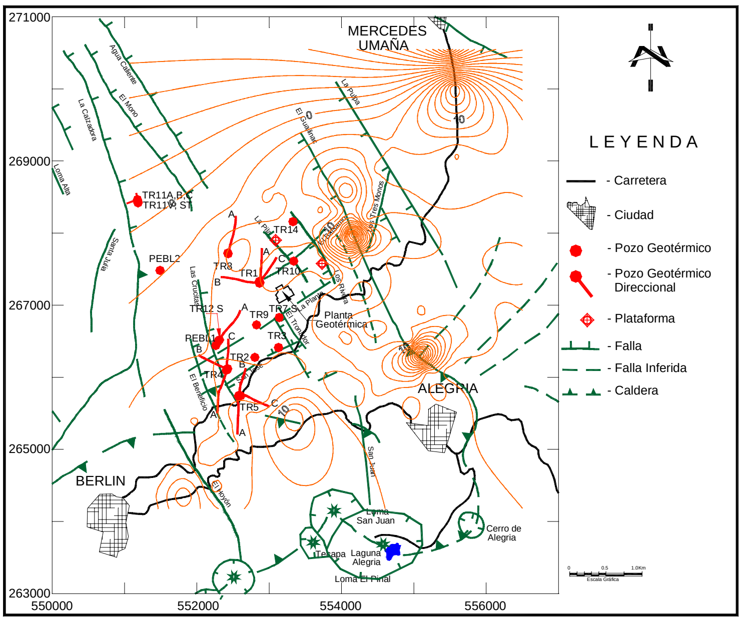


Figure 4: Results of thoron survey at southeast area of Berlin Geothermal Field (0-900 pCurio/L).

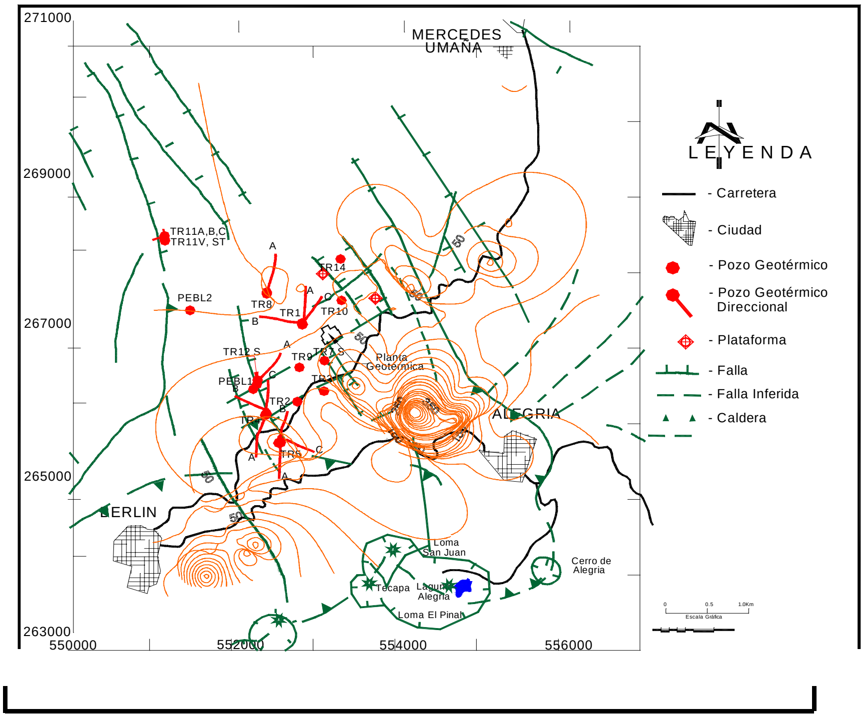


Figure 5: Results of CO_2 survey at southeast area of Berlin Geothermal Field (0-500 g/day-m2).

B. Fumaroles

Results of the monitoring of fumaroles are seen in Table 1, which presents a summary of the characteristics of the fumaroles. Figure 6 shows the distribution of fumaroles in the Berlín geothermal field. Most of the acid alteration is observed at the southern part of the field. High content of sulfur and the presence of sulphate minerals were observed in the fumarole in Laguna de Alegria, which coincides with the upflow zone of the field. Acid-bicarbonate minerals such as gypsum and anhydrite are mostly observed in Tronador fumarole where mixing of fluids has occurred, however, high temperature (<95°C) are also observed in this area. Clay minerals mostly nontronite and montmorillonite are mainly concentrated at the northern part of the field.

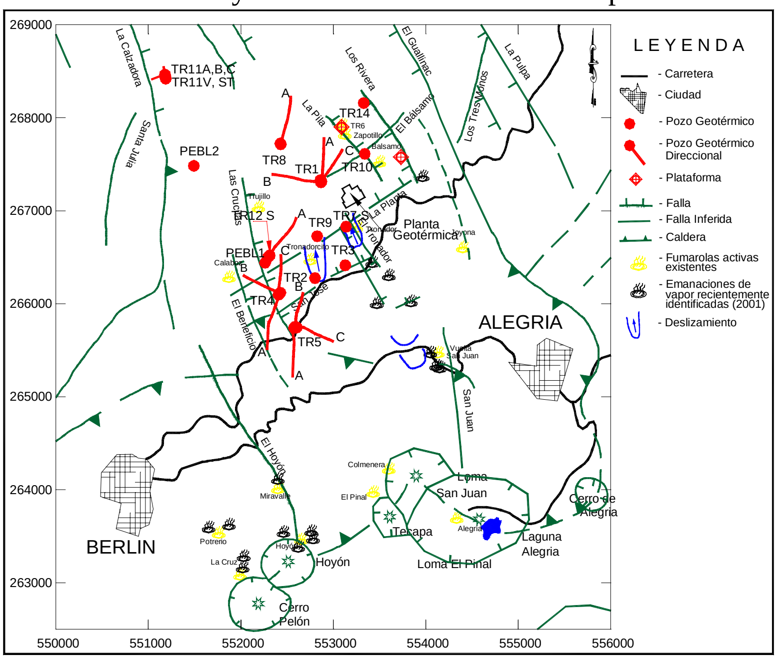


Figure 6: Location of fumaroles in Berlin Geothermal Field.

Table 1: Characteristics of fumaroles in Berlín.

Fumarole	Area (m^2)	Temp (°C)	Mineralogy	Type and intensity of alteration	Related Structures	Type of rock formation
Tronador	21,770.98	83-97	gypsum, hematite, rectorite, alunite, kaolinite, anhydrite, halloysite, nontronite, quartz, heulandite, saponite, albite	Acid aletration, intense	El Tronador Fault, San Jose Fault	Lahars
Tronadorcito	24,389.35	96	anhydrite alunite, amoniojarosite, jarosite, kaolinit pyrite, natroalunite, cristobalite goetite	Acid aletration, intense	San José Fault, La Planta Fault	Lahars
TR-10 (Bálsamo)	16,994.80	94-98	nontronite, alunite, natroalunite, anhydrite, heulandite, cirstobalite, albite, magnetite	Moderate o intense alteration	La Pila Fault, El Balsamo Fault	Lahars
Crater de Hoyon	-		pyrite, sulfur, kaolinite, natroalunite, anhydrite, cristobalite, quartz, albite	Acid aletration, intense	El Hoyon Fault, El Hoyón crater	Lavas by
Laguna de Alegría	3731.81	25-88	halloysite, anhydrite, quartz, pyrite, cristobalite	Acid aletration, intense	Tecapa crater	Lavas by
La Vuelta San Juan	Approx. $60m^2$		nontronite, albite, calcite	Moderate, neutral	San Juan Fault, border of the caldera	Lavas by
La Flecha	8,449.97	80	nontronita y heulandita	Moderate, neutral	El Tronador Fault	Boulders of lavas Lahars y lavas
La Cruz	Approx. $100m^2$	55	albite, calcite, hematite, halite	Moderate, acid aletartion	Berlin- Tecapa volcanic complex	Boulders of lavas Lavas by
El Trujillo	Approx. 100 m^2	92	halloysite, jadeite, corrensite, hematite	Moderate, neutral	Las Crucitas Fault	Lavas by
La Joyona	Approx. $50m^2$	80	saponite, nontronite, cristobalite, albite, jarosite, hematite	Moderate, neutral	San Juan fault	Lavas bm
El Pinal	Approx. $2500m^2$	76-80	nontronite, albite, cristobalite, quartz, halite, magnetite	Acid aletration, intense	Berlin-Tecapa volcanic complex	Lavas by

A schematic diagram (N-S) of the distribution of alteration minerals are shown in Figure 7 where neutral chloride alteration are observed at a lower elevation in Trujillo fumarole, however, fumaroles at the flanks such as La Joyona, la Flecha and Vuelta de San Juan also contain this type of alteration probably due to the materials of landslide which have covered the fumaroles.

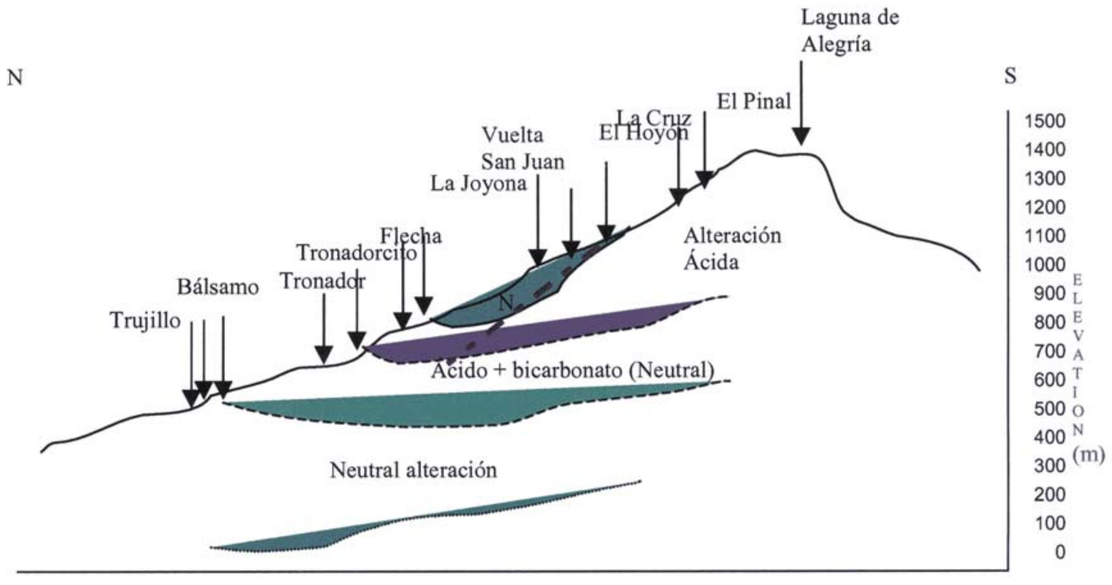


Figure 7: Schematic diagram of the distribution of alteration minerals.

4 Discussion

Most of the permeable zones identified by diffuse degassing coincide with the eastern border of the caldera along the Guallinac fault. Moderate anomalies by thoron survey in the area of Vuelta de San Juan coincide with the clay alteration (montmorillonite and nontronite), a low-grade alteration, which have controlled the release of gases. Materials brought about these clay minerals during landslide (Henríquez et al, 2003).

High CO_2 content coincides with the high temperature and acid-bicarbonate minerals observed along the flanks of the volcanic-complex near fumaroles Tronador and Tronadorcito. The release of magmatic CO_2 and acid sulphate waters brought the formation of anhydrite and gypsum minerals

5 Conclusion

Radon and thoron contents show anomalies at the northeastern part of Alegría City, which could be a possible area for investigation.

The study of gases and alteration mineralogy is very much related. The type of hydrothermal minerals also depends on the permeability and chemical content whether it is gas or liquid.

High and high gas anomaly mainly CO_2 are observed in the central part of the field mainly in Tronador y Tronadorcito fumaroles. Alteration and gas studies confirm the upflow zone of the field.

Almost all of the fumaroles are related with geologic structures, which provided passage for hydrothermal fluids to reach the surface. Likewise, most of the gas anomalies are located in fault zones.

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