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GEOCHEMICAL SURVEYING AND CONCEPTUAL MODEL OF CHILANGUERA GEOTHERMAL SYSTEM, EL SALVADOR

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ABSTRACT

Geoscientific surveys were performed in the Chilanguera geothermal area in El Salvador between years 2004 and 2011. The main objective of this study is to present contribution of geological, geophysical and geochemical surveys for elaboration of the Chilanguera conceptual model. Different criteria were defined in order to identify the main characteristics of the geothermal reservoir. Chilanguera geothermal area is defined as a volcanic geothermal system in the Jucuarán mountain range of 0.63 M.y. age. The heat source has been identified as a sub-volcanic body at 8 km depth. Reservoir is formed by lava rocks belonging to Chalatenango formation, with fluid temperature up to 200°C according to gas geothermometers, thickness of 400 m and located between -800 and 1200 m.a.s.l. Upflow zone is located approximately 500 m south of Laguna Agua Caliente through fracture W-O delineated by structural geology and fluid circulation pattern is towards north through NW-SE and NNE-SSE structures, this alignments were also confirmed by MT strikes and by gravimetric structural alignments. The recharge zone is located in the Jucuarán mountain range and isotopic composition of water indicates that recharge zone is at 600 m a.s.l. Discharge zone is located in the hydrothermal alteration zone in the surroundings of Laguna Agua Caliente.

1. INTRODUCTION

Chilanguera Geothermal Area is located to the southeast of Chaparastique volcano in San Miguel at the eastern part of El Salvador, with an extension of 100 km^2. The Chilanguera Geothermal Area is associated to Jucuarán mountain range (Figure 1).

The first geothermal studies for identification of hydrothermal zones in El Salvador were carried out in 1953. In year 2004 LaGeo S.A. de C.V. conducted exploration surveys in the most eastern part of the country in an area of 640 km^2 included Chilanguera. After these surveys, two main areas were identified: Conchagua in La Unión and Chilanguera in San Miguel. Later in year 2011 LaGeo conducted detailed surveys in both areas and present study focuses on an area of 100 km^2 in size.

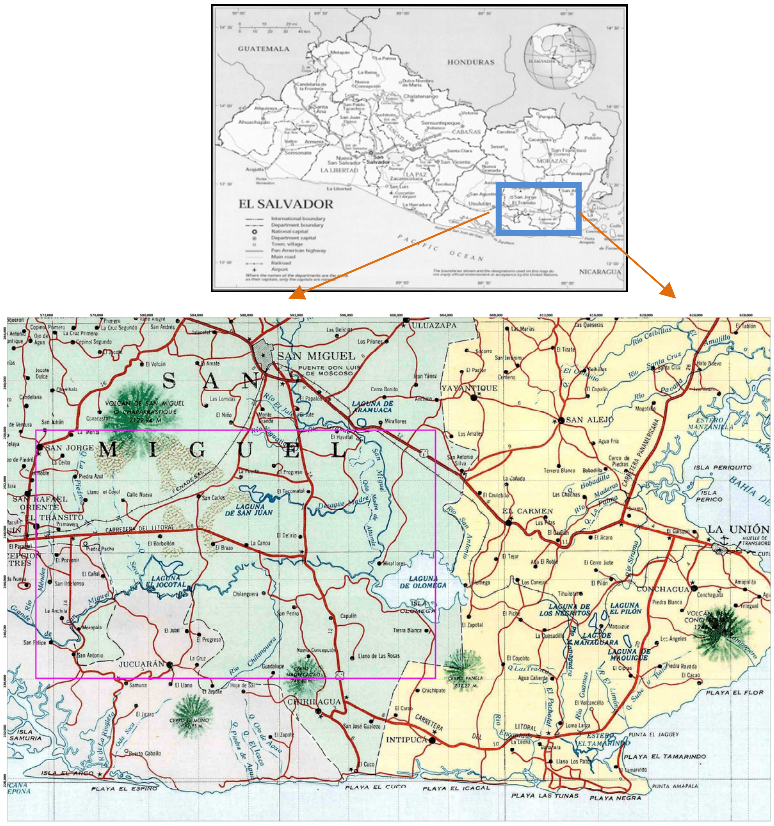


FIGURE 1: Studied area - aerial extension of 100 km^2

2. GEOLOGICAL REVIEW

2.1 Structural geology

The studied area is located in the Chortis Block, there are important features related to tectonic environment that influences the geological evolution of the region, firstly North American Plate moving toward West meanwhile in the south the Caribbean Plate is moving in opposite direction with the formation of Polochic-Motagua Fault; and the last, is the subduction of the Cocos Plate that sinks under the Caribbean Plate, generating an extension E-W of Chortis Block (Figure 2).

These plates interaction produce a fault system which strikes NW-SE as well as extensional zones with the creation of a second fault system which strikes N-S.

2.2 Local geology

The studied area is composed by basic, intermediate and acidic volcanic rocks of Miocene-Recent (Holocene) age. The stratigraphic sequence of the mountain range can be described as follows:

- *Epiclastic deposits*. This unit is located to the west of studied area, this epiclastic deposits are the oldest unit attributable to El Bálsamo formation with Miocene age. These deposits were formed during volcanic activity of Tertiary.
- *Effusive basaltic-intermediate, pyroclastic rocks and volcanic epiclastic subordinated*. This unit is located to the East of studied area and includes the Cerro El Panecito which has andesitic lavas partially altered and by a deposit of pyroclastic flow with subordinated lavic blocks of 15-50 cm, this flow is eroded and hydrothermal altered.

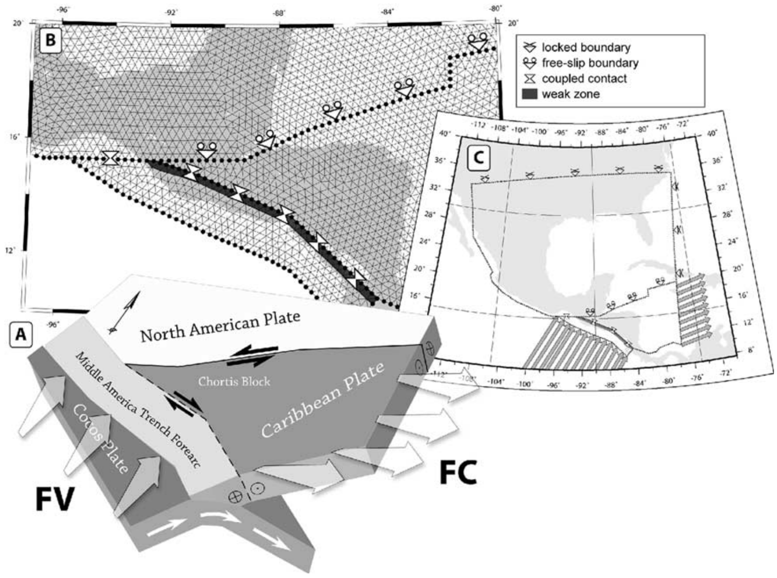


FIGURE 2. Geodynamic conceptual model of the Chortis Block, where FV is the vectorial force of the oceanic trench, FC is the Caribbean plate force (after Alvarez-Gómez, et al. 2008)

In La Joyona and Zúngano creeks fossil geothermal alteration was observed; in the zone of the Cerro el Panecito silicic rocks were observed showing a neutral alteration with chlorite clays, silica and iron oxides; on the other hand, in the Zúngano, alteration is more acid, since pyrite and deposits of sulphur are present.

Deposits of pyroclastic flows of intermediate composition were observed at Jucuarán, there is evidence of partial hydrothermal alteration near the El Jutal, these deposits underlie effusive basic-intermediate unit. This unit belongs to b2 member of El Bálsamo formation of Miocene-Pliocene age.

- *Basic-intermediate effusive rocks*. This unit covers most of the studied area and belongs to eroded andesitic rocks. At the south, at the highest part of Jucuarán mountain range, andesitic deposits are hydrothermally altered. Rocks forming this unit are andesite type, pyroxene andesite with porphyritic texture; on the other hand, to the North there is no evidence of hydrothermal alteration.

  According to Misión Geológica Alemana, 1978, this unit belongs to b3 member of Bálsamo formation of Pliocene age. These deposits overlie effusive basic-intermediate unit, pyroclastic rocks and volcanic epiclastic subordinated.

- *Basic-intermediate lavas and pyroclastic flows from Chaparrastique volcano*. The most important constituents of this unit are andesite-basaltic rocks with porphyritic-vesicular texture, they are present in the northern side of the studied area, and they belong to s2 members of San Salvador formation and come from Chaparrastique volcano.

- *Accumulation cone of Chaparrastique volcano*. This unit belongs to pyroclastic deposits of basic composition erupted by parasitic cones of Chaparrastique volcano. These cones are located in the northern part of the studied area and are composed by two main centres: scoria deposits of Loma de Merlos with 60 m high and diameter of 200 m and Cerro El Borbollón which is composed by thin layers of pyroclastic deposits and ash. This hill is 110 m high y 900 m diameter.

- *Quaternary flood deposits.* They are the most recent deposits eroded from highest places, transported and deposited in the lower parts by floods of water. These deposits are thin and cover the Laguna el Jocotal and Laguna Agua Caliente which is 50% of studied area.

2.3 Petrographic analysis

The studied area is comprised of many volcanic edifices that make up the Jucuarán mountain range, so have obtained a variety of rock composition of basic, intermediate and acidic. Petrographic analysis provides information about different types of rocks present in the studied area.

- *Basalts.* This group of rocks was found mainly at the southeast of Jucuarán city and belongs to a dike of basaltic composition.

- *Andesite-basaltic*. Lava flows of andesite-basaltic composition have been classified by its low content of Olivine 2-3%, pyroxenes 7-10%, plagioclase 20-25% and opaque minerals 1-3%. Most of these flows belong to basic-intermediate effusive unit from Chaparrastique volcano.

- *Andesite.* Lava flows of andesite composition are the most predominant in the studied area; they are divided into two groups: andesite and andesite-pyroxene. Secondary minerals as calcite 1-3%, chlorite clays 1-5%, quartz 1-2% and iron oxide 1-5% are present.

2.4 X-ray diffraction analysis

Ten samples were collected in different zones of fossil alteration in the Jucuarán mountain range for X-Ray diffraction analysis at LaGeo Geological Laboratory. The main found minerals belong to Argillic facie of a hydrothermal system where the most abundant minerals are montmorillonite which is clay of the low temperature smectite group.

There is another mineralogical assembly which is characteristic of Argillic zones, calcite, quartz, montmorillonite, halloysite, and cristobalite minerals are present suggesting temperature in the range of 100°-120°C.

Laguna Agua Caliente reveals the presence of gypsum also suggesting low temperatures and represents evaporite deposits.

2.5 Geochemistry of rocks

Geochemical analysis of rocks was performed in order to determine the origin and different types of rocks existing in the studied area. Seven samples were analysed by X-ray fluorescence at Geochemistry Laboratory of Universidad Nacional Autónoma de México.

Results of analysis suggest that two main groups of rocks are present in the studied area; the first one is andesite rocks of intermediate composition which is representative of lava flows in the area, the second is the pyroclastic flow which is divided into two events: the ones of dacitic composition and the ones of rhyolitic composition. See TAS diagram after Le Bas et al., 1986 Figure 3.

Geochemical analysis of andesite rocks shows that SiO_2 and oxides of major elements content are high, suggesting that the magmatic chamber feeding the volcanoes of Jucuarán mountain range are not deep enough because parent magmas of lava flows present in the area are evolved magmas.

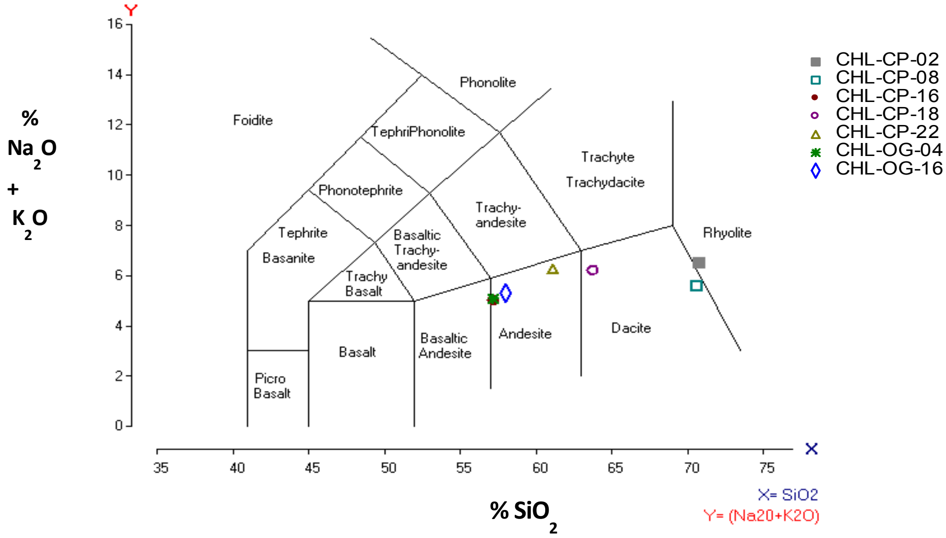


FIGURE 3: TAS diagram shows volcanic rocks of Chilanguera geothermal area (after Le Bas et al., 1986)

2.6 Hydrothermal manifestations

Hydrothermal manifestations in the studied area are located in the surroundings of Laguna Agua Caliente mainly consisting in hot springs and fumaroles at the southeast margin of the lagoon. Some hot springs are extended to the East and some others to the North where temperature decreases.

Hot springs and fumaroles are located in a small portion of the studied area temperatures ranged between 31 and 102°C; highest temperatures were measured in domestic wells at the south and East of Laguna Agua Caliente.

There is evidence of hot springs alignment at the end of Jucuarán mountain range slopes suggesting structural control. The presence of a main structure at the south of hot springs with E-W orientation dipping to the North, can be correlated to the southern margin of central depression, confirm this structural control.

3. GEOPHYSICAL DATA

3.1 Gravimetric surveys

Different gravimetric surveys have been carried out in the Chilanguera geothermal area. Surveys were conducted in the years 2004, 2008-2009, and 2011. 770 surveys were conducted up to year 2011 with an average spacing between measurements of 1000 m and represent a regional coverage of approximately 1500 km^2 including San Miguel volcano, Conchagua and Chilanguera geothermal areas. This density of points gives a very good resolution of observed gravimetric anomalies in both local and regional perspective.

In the last two surveys a Scintrex CG-5 model was used and each gravimetric point was positioned with double frequency GPS in cinematic mode with minimum time data logging of three minutes. Data was filtered, assessed and processed using Gravmaster software (Geotools) and exported to WingLink (Geosystem) for calculation of Bouguer grid anomalies, residual anomaly and application of some filters as first horizontal derivative, first and second vertical derivative, interpretation an correlation with resistivity studies. GPS data were processed using Trimble Geomatic Office (Trimble) and Surfer software was used for map visualization.

Figure 4 shows Bouguer anomaly with density of 2.3 g/cm^3, the white line differentiates between maximum and minimum gravimetric values and represent an isocontour of 30. Zones with values lower than 30 are considered as gravimetric minimum values.

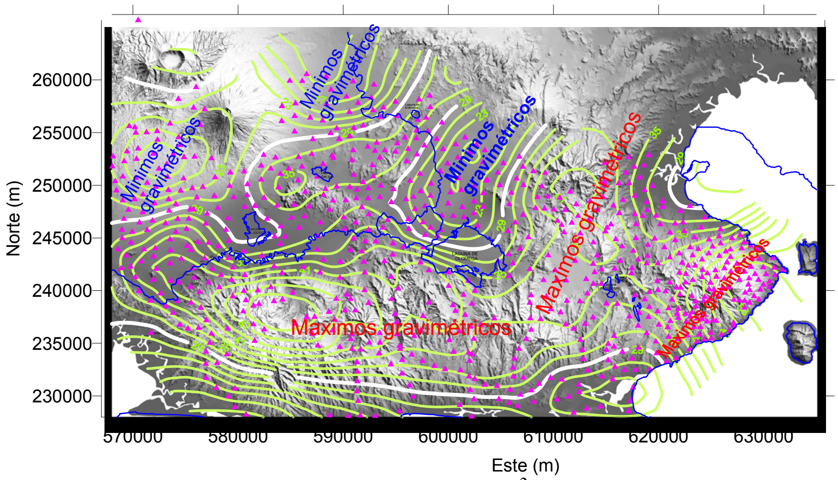


FIGURE 4: Bouguer anomaly map for a 2.3 g/cm^3, contour intervals every 3 mGal

Maximun values of the Bouguer anomaly appear concentrated on the Jucuarán mountain range W-E oriented, then this maximum values drift toward North in the eastern part of Laguna de Olomega. A regional alignment is observed with W-E direction parallel to the coast at the south of Jucuarán mountain range and could be defining big regional structures probably associated to southern edge of the central graven or to the subduction zone.

Figure 5 shows the residual anomaly map at density of 2.3 g/cm^3. Typically a residual anomaly shows local structural characteristics of the studied area differentiated by positive and negative gravimetric anomalies i.e. high and low rock density. Positive anomalies are associated with very well-consolidated rocks due to mineralization, compaction and type of rock. Positive anomalies are related to Jucuarán Mountain range and some areas towards North. In zones with hydrothermal alteration, to the North of Jucuarán mountain range, are represented by positive anomalies. A very good correlation exits between positive and negative gravimetric anomalies and the structural geology.

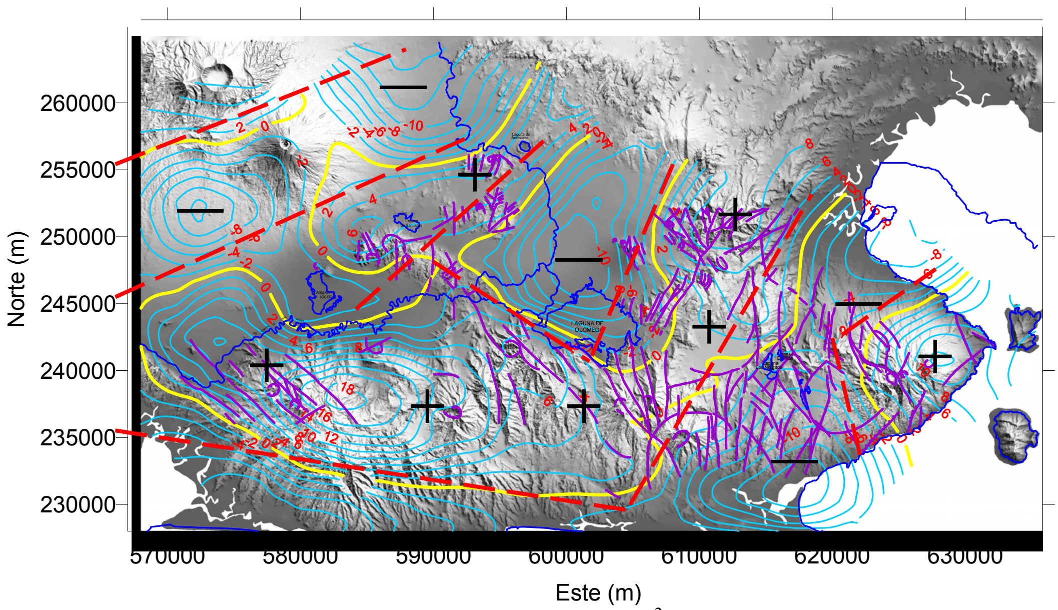


FIGURE 5: Residual anomaly map with density of 2.3 g/cm^3. The yellow line represents cero value of residual anomaly map. Purple lines depict structural geology alignments. Dashed red lines represent suggested structures based on cero value of residual anomaly

In general, there are structural contour lines defining a WNW-ESE direction, consistent with Jucuarán mountain range and other systems with NE-SW orientation. Some local structural systems contour lines are aligned with the residual anomaly.

According to gravity survey, there are indicators that a possible major geothermal area is associated with a heat source of the Jucuarán mountain range that the San Miguel volcano since this is located on a negative anomaly zone.

The grid of Bouguer anomaly as well as the residual anomaly were used in depth analysis to calculate the power spectrum through the Fast Fourier Transform, it was estimated that the bodies that produce anomalies are at 0.4, 2.1, 4.3 and 8.8 km.

3.2 MT and TDEM surveys

Electrical resistivity DC surveys were carried out in Chilanguera in year 2004 and they included 60 electrical pits and 45 vertical electrical soundings (VES). This survey was used for delimitation of 100 km^2 study area where main physical anomalies were present.

In year 2008 a complementary electrical resistivity survey was conducted and 23 MT soundings were included. Penetration capacity of VES is affected by the presence of shallow aquifers, for this reason in year 2010 MT and TDEM soundings were conducted with the main objective of getting information related to deeper electrical stratigraphy in the studied area.

Data collected from soundings were processed and modelled using 1D technique and one 2D profile was also analysed with the main objective of characterization of the main productive reservoir and the seal layer for well targeting proposes.

3.2.1 Strike analysis

In Chilanguera, the strike map for a frequency of 0.5 Hz (0 to 1500 m) shows preferential directions where fluids circulate in NW-SE, NE-SW and W-E orientation (figure 6) which are well correlated to local fault system in the studied area and playing an important role in the circulation of geothermal fluids.

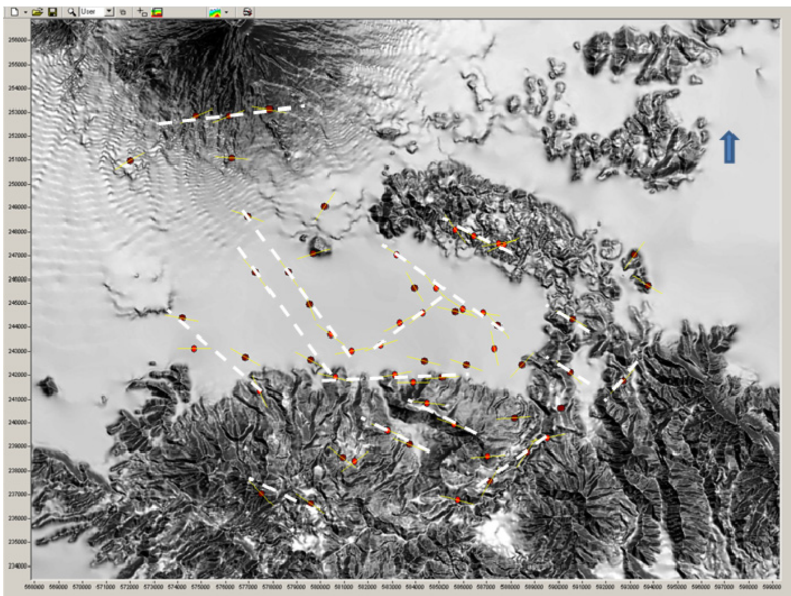


FIGURE 6: Structural alignment suggested by a strike map at 0.5 Hz (0-1500 m depth)

3.2.2 1D and 2D models.

1D model was performed using WinGLink software with Occam algorithm and shows the presence of deep resistive layer with resistivities higher than 30 ohm-m underliying a conductive layer of variable thickness at 400-600 m depth and resistivity values lower than 10 ohm-m.

Figure 7 shows correlation between 1D profiles NE-SW oriented. Resistive layers are shown in blue with values higher than 20 ohm-m and conductivie layer is depicted by resistivity values lower than 10 ohm-m in red. Plain stratigraphy and thickness of conductive layer suggest that this profiles are located in the margin of the main hydrothermal zone and are representative of low temperature minerals associated with discharge zone of geohtermal system.

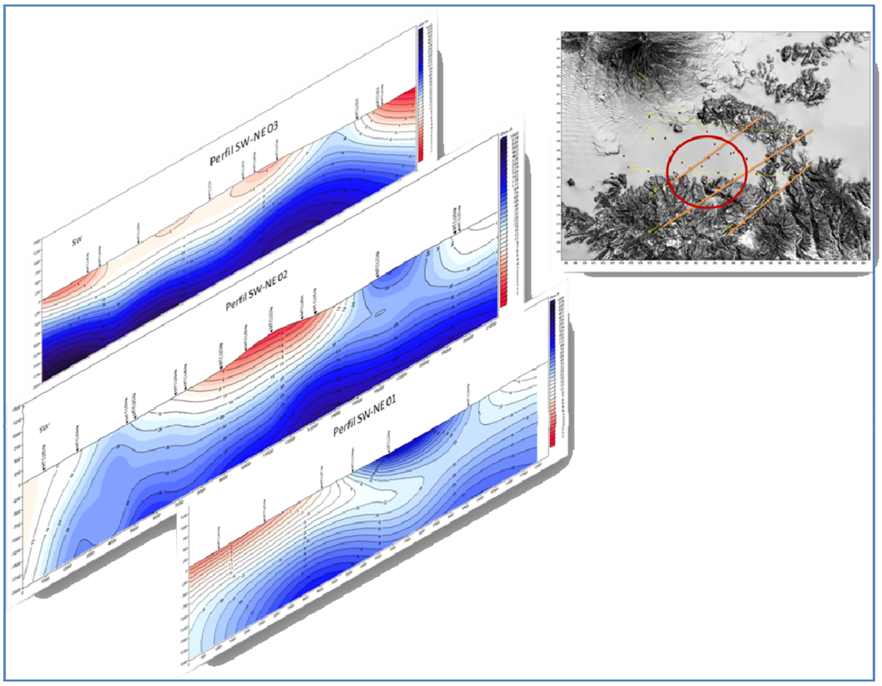


FIGURE 7: 1D correlation profiles with NE-SW orientation

There is an agreement between different 1D profiles suggesting that the zone of interest for geothermal exploration is the one showed in the red circle of Figure 7, in addition suggest that the upflow zone is located below the area where profile shows resistivity values below 5 ohm-m. This suggests that the heat source is associated to an intrusive body of the Jucuarán volcanic system.

Results of 2D modelling are shown in Figure 8 and the main characteristics of this section are as follows:

There is a well-defined conductive layer with values lower than 10 ohm-m going deeper since the surface up to -600 to -800 m a.s.l. This layer is associated to impermeable clays and represents the seal cap of the geothermal reservoir (Figure 8). The section suggests the presence of resistive dome identified at 800 m depth depicted by the white dotted line. The possible reservoir is bounded by resistivity values between 20 and 90 ohm-m which is located between -800 and -1200 m a.s.l.

The main zone of interest is located in the central section of 2D profile in figure 8 and is the best option for well targeting.

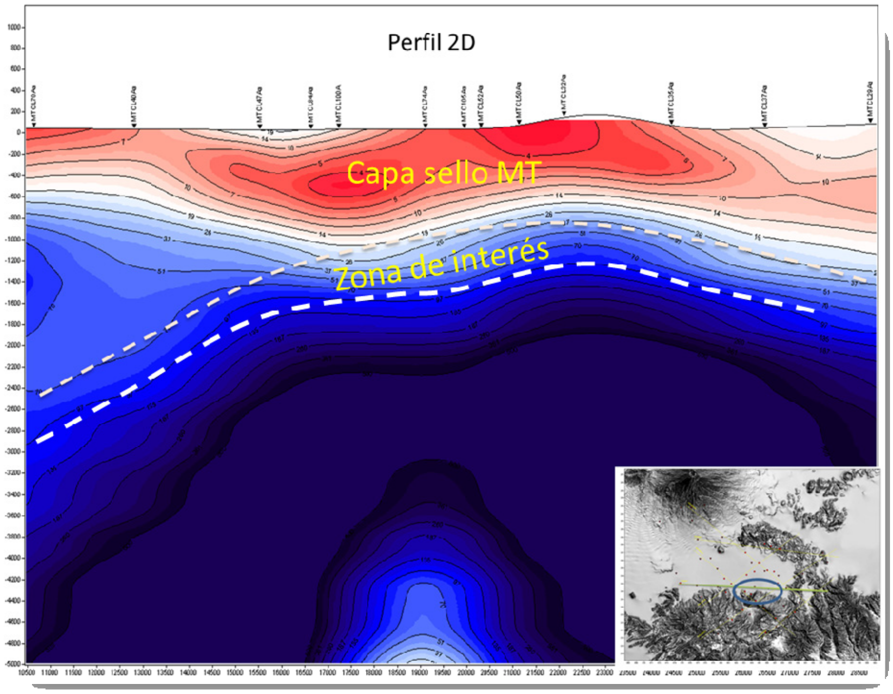


FIGURE 8: Seal cap and possible reservoir from MT/TDEM survey

4. GEOCHEMISTRY OF FLUIDS

4.1 Geochemistry of water

Geochemical exploration started in 2004 in an area of approximately 640 km^2, at that time a total of 53 water and steam samples from cold and hot springs, domestic wells, lagoons and fumaroles were collected. Twenty four new sites were sampled in addition in year 2011. Map in Figure 9 show places where samples were collected.

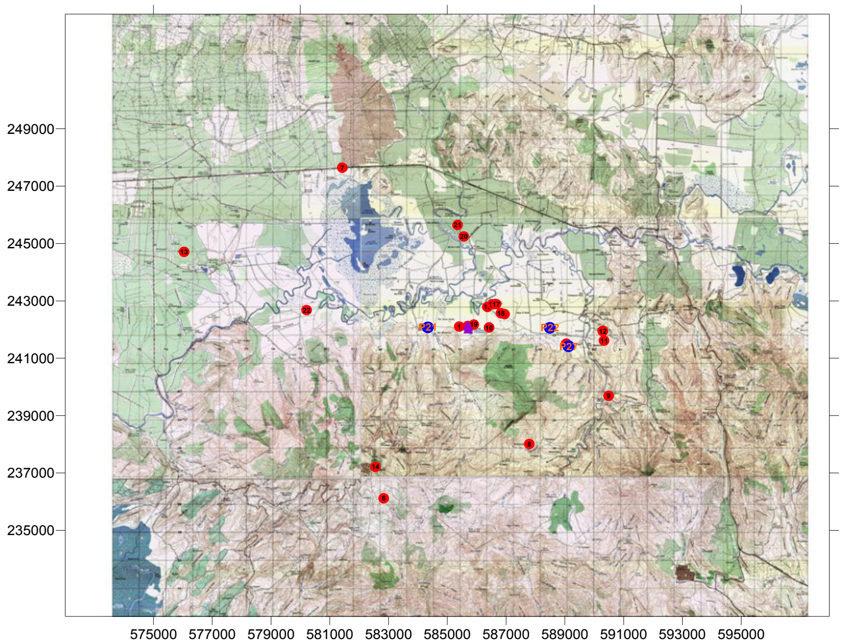
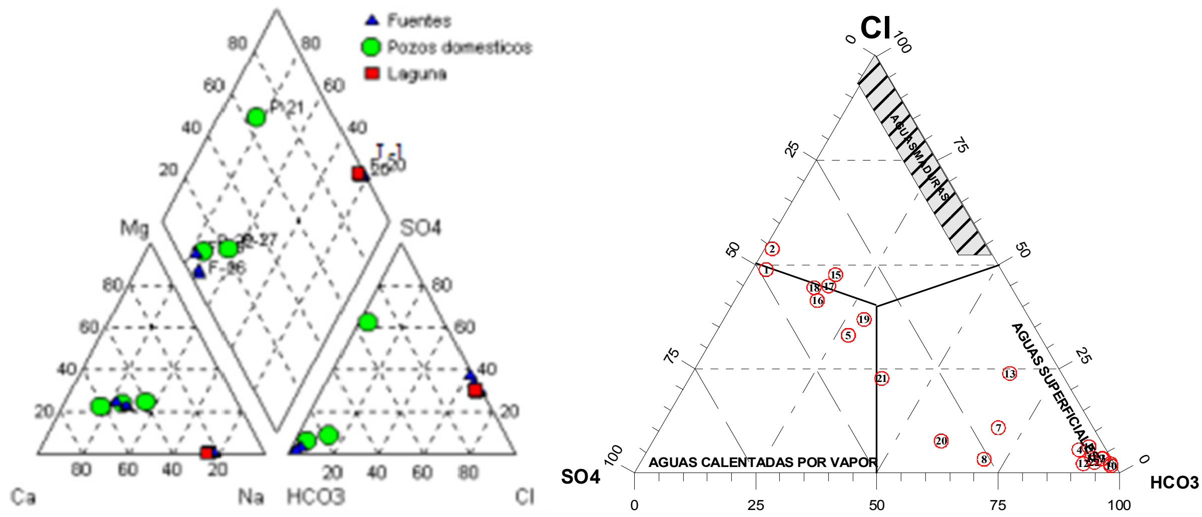


FIGURE 9: Location map for chemical sampling in the Chilanguera geothermal area

Samples localized near Laguna Agua Caliente and in the margins of the lagoon are Na-Cl-SO_4 type with evidence of geothermal composition. Sampling temperature ranged between 40-50°C. Remaining samples show bicarbonate composition and lower temperatures (figure 10).

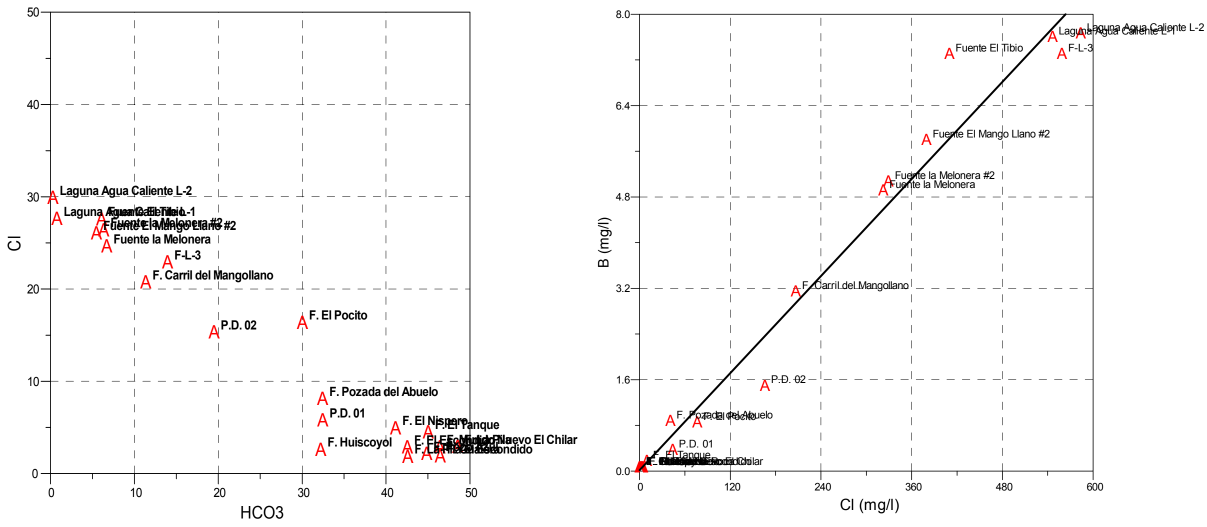


(a) (b)

FIGURE 10: a) Piper and b) Cl-SO_4-bicarbonate diagrams for waters from Chilanguera geothermal area

Figure 11 shows the Cl-HCO_3 relationship as assessment of type of waters and presence of end members (chloride and bicarbonate waters) as well as intermediate members suggesting mixing processes. The same relationship is shown in the Cl-B diagram where boiled waters show higher chloride concentration.

Na-K relationship (Figure 12) confirms this hypothesis; waters from Laguna Agua Caliente are from geothermal origin and mix with cold water coming from East and South in the studied area.



(a) (b)

FIGURE 11: a) Cl-HCO_3 and b) Cl-B relationship for waters of Chilanguera area

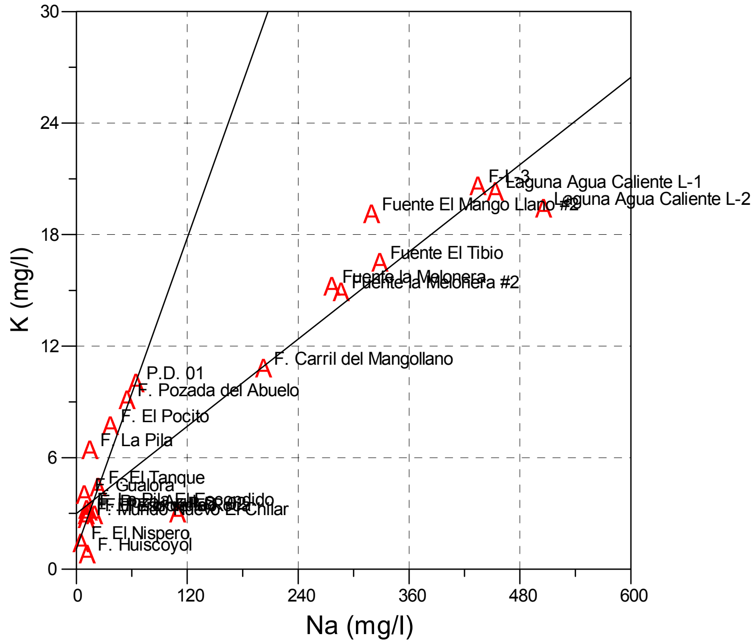


FIGURE 12: Na-K relationship (in mg/l) for waters from Chilanguera area

4.2 Isotopes

Isotopic composition of studied waters is shown in Figure 13, sample L2 from Laguna Agua Caliente shows high evaporation. Fuente el Magollano is from geothermal origin and fits in the same evaporation line than sample L1 showing low water-rock interaction suggesting low deep temperature.

Fuente Guarola shows more negative isotopic composition suggesting that the most probable recharge zone is at 600 m a.s.l.

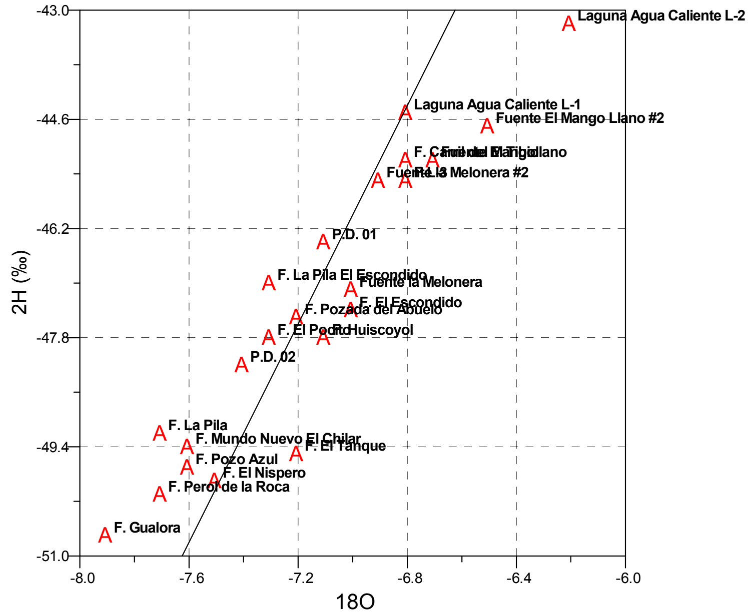


FIGURE 13: ^{18}O-^{2}H isotopic relationship (in ‰)

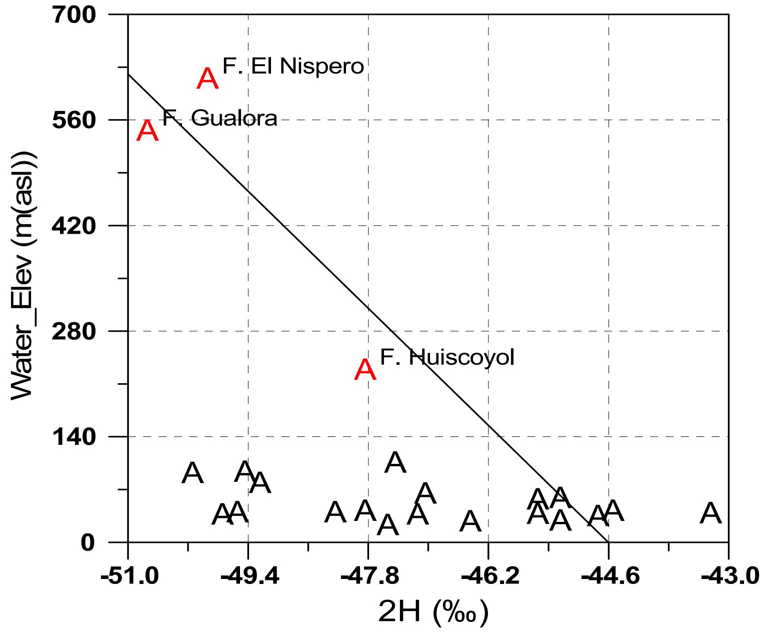


FIGURE 14: ^{18}O (in ‰) - elevation relationship

4.3 Water geothermometry

Table 2 shows results of cation geothermometers for Chilanguera area, geotemperatures range between 100-150°C.

TABLE 2. Temperature of water in Chilanguera area
:

ID	Lugar de Muestreo	Punto de Muestreo	Na	K	Ca	Mg	Cl	SO4	HCO3	SiO2	Nak F/T 73	NaK F79	NaK Arn83	NaKCa F/T73	Calcedonia Fournier 77	Calcedonia Arnorsson 83	Cuarzo F/P82	Cuarzo Arnorsson 85 (max steam loss)
1	L Agua Caliente, Cton. Chilanguera	L-1	456	20.3	123.2	1.45	548.2	543.58	30.6	124	106	156	125	142	124	122	150	145
2	L Agua Caliente, Cton. Chilanguera	L-2	508	19.4	114	0.0521	585.6	486.06	16.07	127.5	94	146	114	137	126	123	151	146
5	Cton. Chilanguera	F. Carril del Mangollano	205	10.8	49.8	7.54	208.6	248	173.51	102.3	120	168	138	144	112	110	139	135
15	Chilanguera	F El Tibio	331	16.5	96.8	2.58	412	300.42	152.56	81.2	115	164	133	144	98	97	126	124
16	Chilanguera	F la Melonera	279	15.2	60.4	2.21	324.2	325.39	132.91	106.8	123	170	140	149	115	113	141	137
17	Chilanguera	F la Melonera 2	289	14.9	59.1	3.63	331.3	276.47	129.64	107.9	118	166	136	147	115	113	142	138
18	Chilanguera	F Mango Llano 2	322	19.1	70.9	2.39	381.5	348.87	126.41	126	130	176	147	154	125	123	151	145
19	Laguna Agua Caliente	F-L-3	437	20.6	114.8	0.4116	560.9	520.36	439.16	133.1	110	160	129	144	129	126	154	148
21	Cantón El Brazo	P.D. 02	112	3	94.6	30.23	167.8	277.49	292.14	101.3	69	125	91	103	111	110	138	135

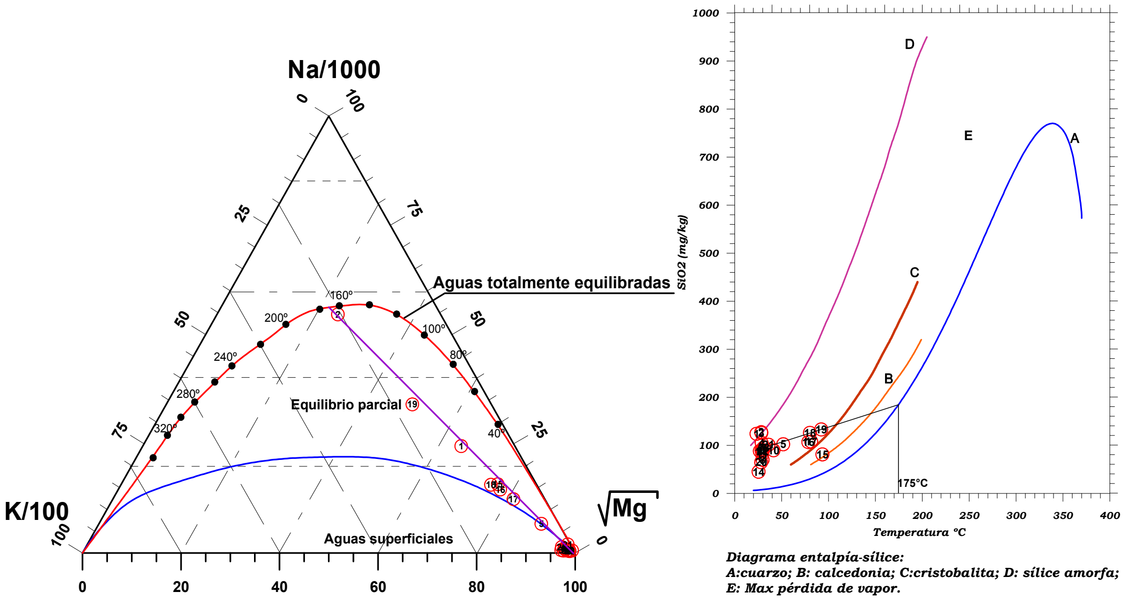
Giggenbach diagram in Figure 15 shows that estimated temperature is 170°C and temperature of mixing diagram is 175°C.

4.4 Gases

Fumaroles and boiling water was sampled in Laguna Agua Caliente. Origin of gases may be inferred using ternary diagram N_2-He-Ar (Giggenbach, 1980). Gases are from magmatic origin but meteoric influence was also observed (Figure 16). Degasification is also present as product of interaction with surrounding water. Gas geothermometers show temperatures between 150-250°C (Table 3).

TABLE 3: Gas geothermometer temperatures

ID	Lugar de Muestreo	Punto de Muestreo	$T_{DP(1)}$	$T_{H2S-CO2(2)}$	$T_{CO2(3)}$	$T_{H2S(3)}$	$T_{H2S(3)}$	$T_{H2(3)}$	$T_{H2(3)}$	$T_{CO2/H2(3)}$	$T_{H2S/H2(3)}$	$T_{CO2/N2(4)}$	$T_{CO2-H2S(4)}$	$T_{CH4/CO2}$
1	Cton Chilanguera	Laguna Agua Caliente Gas-1	152.69	220.54	227.11	255.48	185.82	234.24	137.31	241.63	215.56	189.31	248.33	270.79
2	Cton Chilanguera	L. Agua Caliente Hervidero Gas-3	155.96	205.96	189.29	246.68	173.45	228.69	127.47	244.42	212.53	191.'8	241.11	246.97



(a) (b)

FIGURE 15: a) Giggenbach diagram (1988) b) Silica geothermometer

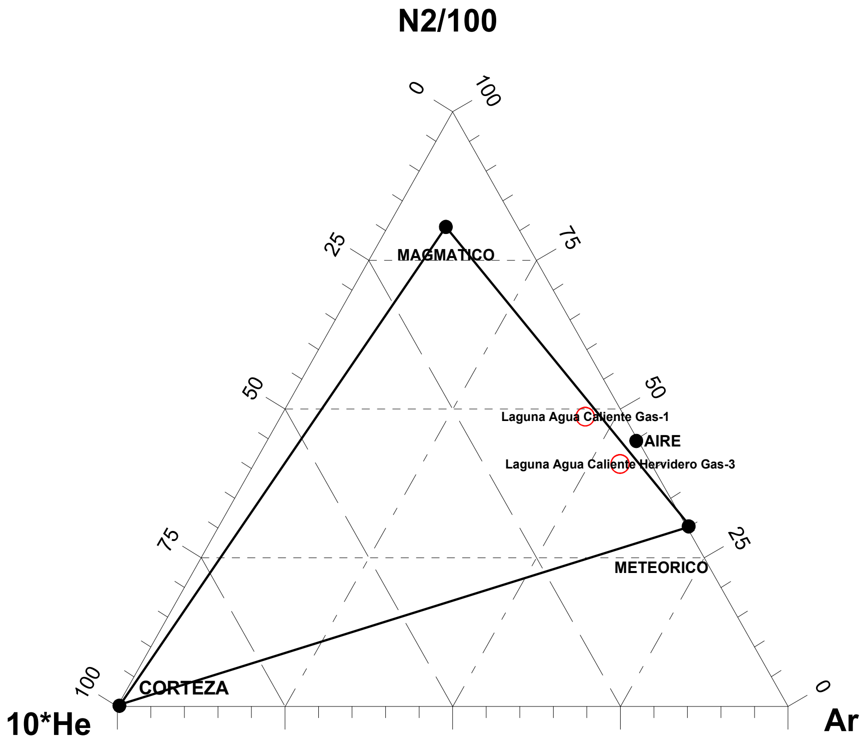


FIGURE 16: Relative content of N_2-He-Ar (Giggenbach, 1980).

4.5 Diffuse degassing

Diffuse degassing surveys were conducted in year 2004 in aproximately 640 km^2 in an area located southeast of Chaparrastique volcano in San Miguel. CO_2 flux, radon and thoron gases were measured in 217 points with separation of 1.5-2 km from each other, see Figure 17.

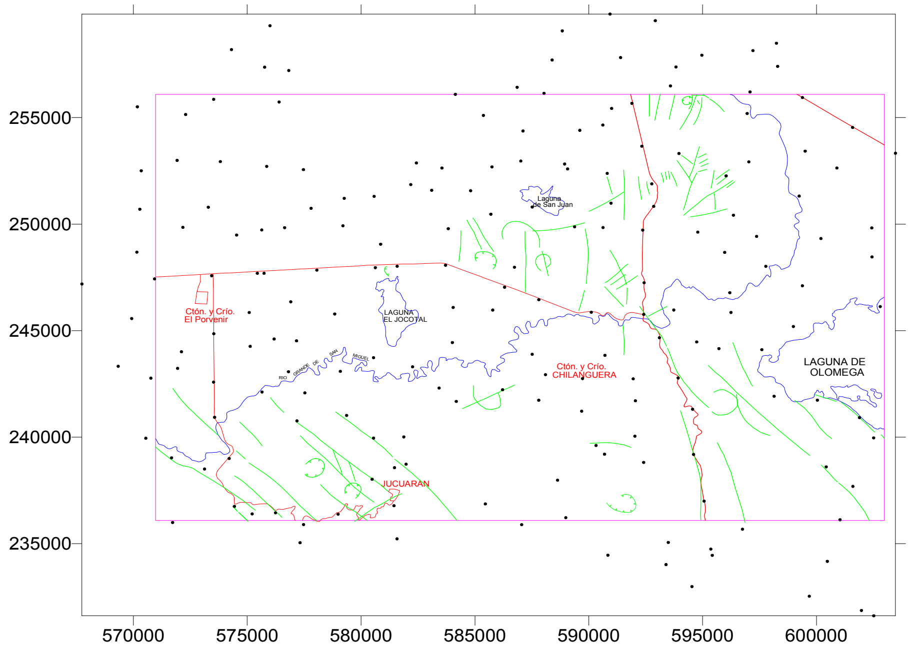


FIGURE 17: Location sites for difusse degassing monitoring in Chilanguera

4.5.1 CO_2 flux (g/m^2-day)

Measured values range between 60 and 130 g/m^2-day, background value is 25 g/m^2-day, higher values are associated to faults and structures in the estudied area.

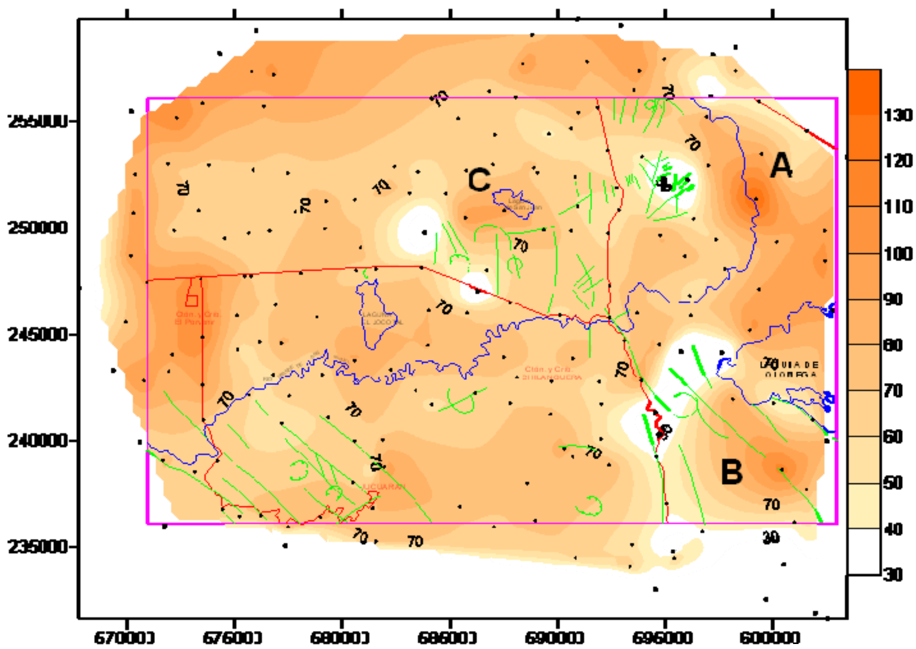


FIGURE 18: CO_2 flux distribution map

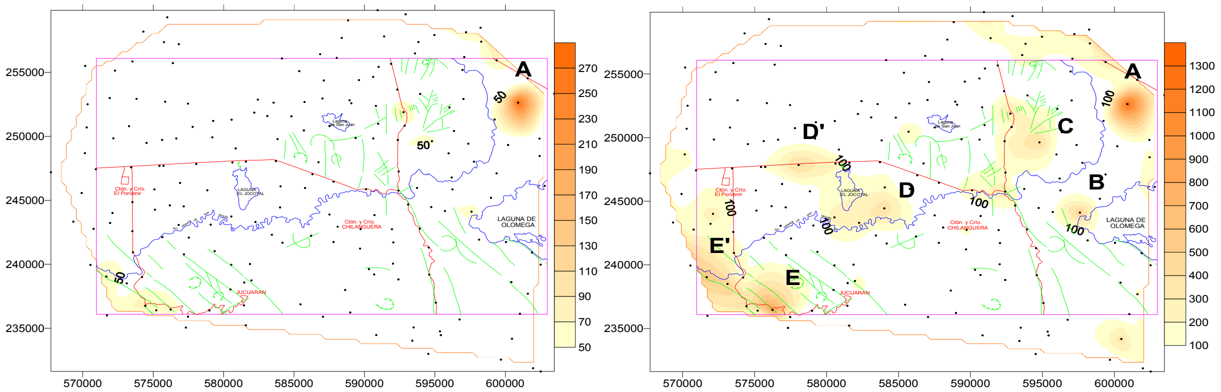
Anomalies B and C in Figure 18 are related to comfirmed structures in the studied area and both are therefore considered active faults. Anomaly A suggests the presence of another estructue which is comfirmed by presence of a radon anomaly, therefore the existence of a structure that is capable of flow transport in a convectively way is confirmed.

4.5.1 Radon and thoron

Radon and thoron anomalies can be observed in Figure 19, where anomaly A is consistant for three mentioned gases (CO_2, Radon and Thoron). In adition Thoron anomalies B, C, D-D’ and E-E’ were ploted. Anomaly D-D’ have good correlation with main structures observed in the studied area.

4.5.2 Thoron/Radon ratio

Thoron/radon ratio defined high permeability and vertical ascent of fluids. Anomaly B-B’ suggests that a high permeability circular structure is present and probably overlaying recent volcanic deposits (Figure 20).



(a) (b)

FIGURE 19: a) Radon and b) Thoron distribution maps

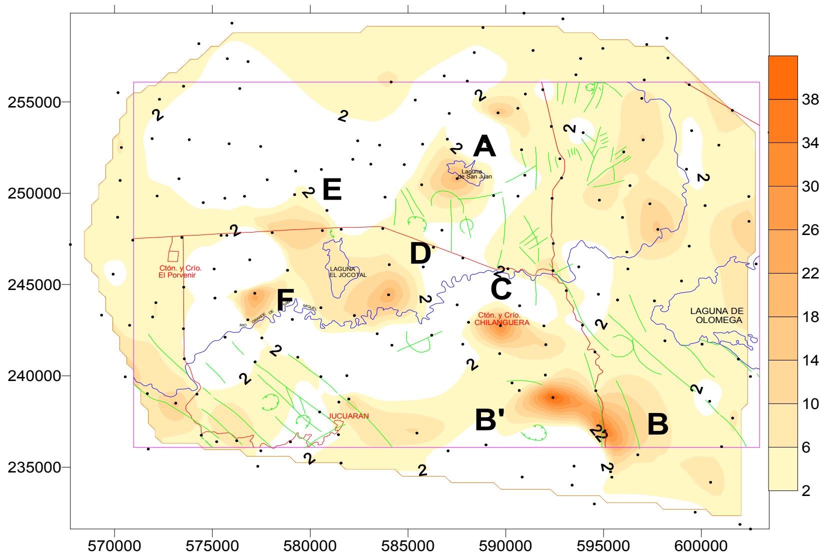


FIGURE 20. Thoron/Radon ratio distribution map

5. CONCEPTUAL MODEL

Geoscientific criteria has been defined for elaboration of the Chilanguera geothermal area conceptual model. Table 4 sumarizes main results of geoscientific surveys describes in previous chapters. The conceptual model of the geothermal area is shown in Figures 21 (cross-section with a rough sketch) and 22 (which shows a planar view).

TABLE 4: Geoscientific criteria for elaboratorion of conceptual model in Chilanguera

Reservoir characteristic	**Geoscientific criteria**		
	Geology	**Geochemistry**	**Geophysics**
Heat source	Sub-volcanic in the Jucurán mountain (dyke 0.63 M.a.)	?	Positive gravimetric anomaly supported by grvimetric spectral analysis (8 km depth)
Reservoir	Lavas from Chalatenango formation	Equilibrated aquifer 150-180°C (water geothermometer) a cerca de 200°C (gas geothermometer). Magmatic gases.	Reservoir between 40 and 90 Ohm-m, between -800 and -1200 m
Seal Cap	Pyroclastite and epiclastite from El Bálsamo formation (b1 unit)	?	Cunductive strata since surface up to -600 to -800 m
Fluid circulation pattern	Upflow zone approximately 500 m toward south of Laguna Agua Caliente though fracture E-W (Cerro Panecito) moving to the north by NW-SE and NNE-SSW structures	Mixing process geothermal and cold water	NW-SE and NNEa-SSO alignments defined by MT srikes and gravimetric structural alignments
Recharge zone	Jucuarán mountain range	Isotopes: Jucuarán mountain range at 560-600 m.a.s.l. (Guarola and El Níspero springs)	?
Discharge zone	?	Zone of hydrothermal manifestation near Laguna Agua Caliente	?

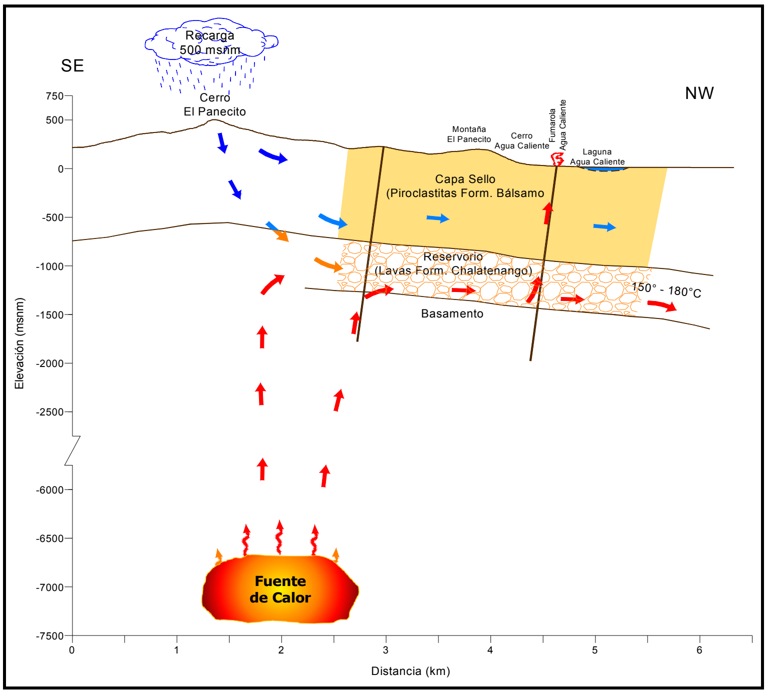


FIGURE 21: Chilanguera conceptual model sketch.

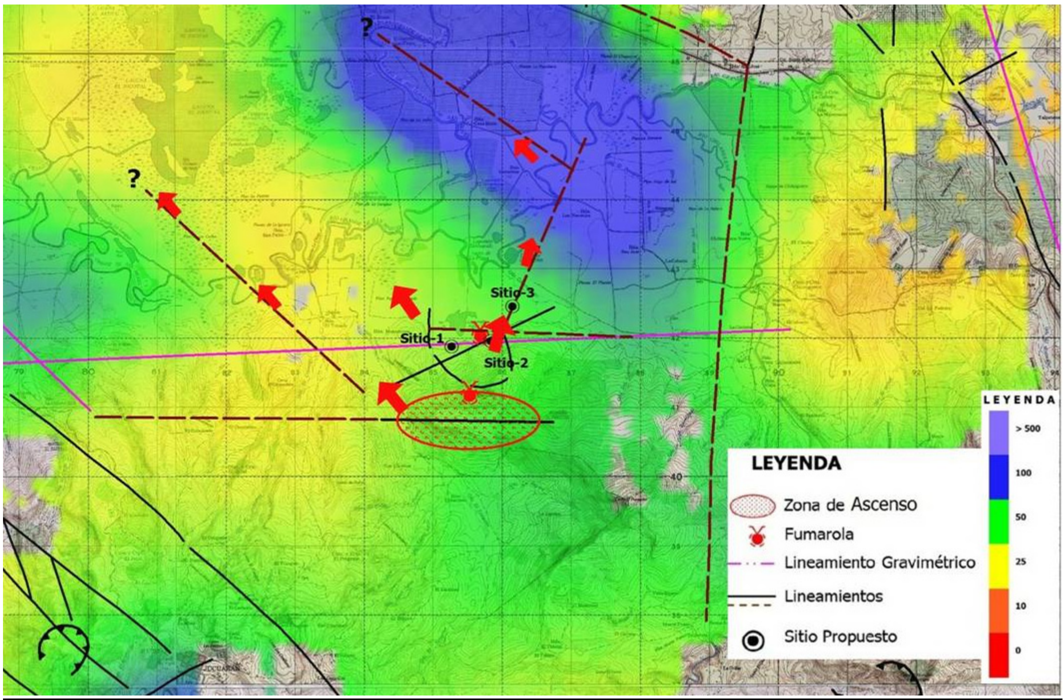


FIGURE 22: View of the Chilanguera conceptual model, resistivity values at -1000 m

6. CONCLUSIONS

Geoscientific studies have been performed in Chilanguera for elaboration of Chlilanguera conceptual model between years 2004 and 2011. A geothermal reservoir of volcanic origin with temperature between 150 and 200°C has been defined at 1200 m depth, thicknes of 400 m.

Area of interest of 0.8 km^2 for exploratory drilling has been delineated by 2D resistivity modeling with the main objective of intersection of transition zone between shallow conductive and high resistivity dome.

In order to improve resolution of Thoron/Radon ratio anomaly in the suroundings of Laguna Agua Caliente, distance between difussive degassing measurements should be reduced in the grid.

REFERENCES

Alvarado, et al, 2008: *Forearc motion and deformation between El Salvador and Nicaragua: GPS, seismic, structural, and paleomagnetic observations.*

Giggenbach, W.F., 1988: Geothermal solute equilibria. Derivation of Na-K-Ca-Mg geoindicators. *Geochim. Cosmochim. Acta, 52*, 2749-2765.

Giggenbach, W.F., 1980: Geothermal as equilibria. *Geochim. Cosmochim. Acta, 44*, 2021-2032.

I.G.N., 1968: *Mapa geológico general de la República de El Salvador.*

Misión Geológica Alemana; 1978: *Mapa geológico de la República de El Salvador.*