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LaGeo S.A. de C.V.

GEOCHEMICAL EXPLORATION IN CHINAMECA GEOTHERMAL FIELD, EL SALVADOR

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ABSTRACT

This paper presents the geochemical results of the exploration studies in Chinameca, a new geothermal field in the eastern part of El Salvador. Exploration was undertaken in 2005 and the geoscientific results led to the drilling of two geothermal wells in 2009. Geochemical studies gave a reservoir temperature of 240–260 ^{o}C (based on Giggenbach and cationic geothermometers). The meteoric recharge of the geothermal system was identified by stable isotopes located at the volcanic complex of Chinameca and the graben system at the northern part of the field. A geochemical conceptual model is presented which agrees with the results obtained.

1. INTRODUCTION

El Salvador has undertaken several geothermal projects to generate electrical energy. At present, two geothermal fields, Ahuachapán and Berlin, produce about 188 MW, which contribute 25.1% to the national energy production of the country. According to the National Policy of Energy, there is a necessity to increase the production of electricity, which urged La Geo S.A. de C.V to conduct several exploration studies in the country.

In 2005, exploration studies were carried out at the Chinameca geothermal area, located 90 km east of San Salvador. The results obtained from these studies led to the drilling of two geothermal wells and was proven to be very promising, with temperatures between 230 and 240°C (the wells are currently in the recovery period).

2. GEOTHERMOMETRY

During the ascent of geothermal waters from the deep reservoir to the surface, they may cool by conductive heat loss as they travel through cooler rocks, or boiling due to the decompression of the fluid. Cooling may change its degree of saturation with respect to both primary and secondary minerals. Boiling changes the compositions of the rising geothermal waters. These include degassing and increase in the solute content of the water due to steam loss.

When applying geothermometers, it is assumed that no change in water composition occurs with conductive cooling and boiling when the water flows up to the surface. Another assumption is the temperature depends on the chemical equilibrium of the reservoir. These assumptions are not actually true in both cases, but just the ideal process. However, water is usually in equilibrium with quartz as well as with alkali feldspar, and the solution is invariable in geothermal reservoirs, at least when the temperature exceeds 150-180°C (Arnorsson, 2000).

According to Arnorsson (2000), experience shows that results for different geothermometers sometimes compare well for a particular discharge, although sometimes large differences are seen. Good conformity between individual geothermometers is usually taken to indicate that the assumption of equilibrium is valid and that faith can be put in the results. Discrepancy in results, on other hand, is indicative of disequilibrium. A discrepancy may, however, be utilized to quantify various processes in geothermal systems such as boiling and mixing with cooler water in out flow zones. Therefore, differences in the results of individual geothermometers need not be a negative outcome for their interpretation.

Geothermometers can be classified in two groups: a) temperature dependent on variations in solubility of individual minerals and b) temperature dependent on exchange reactions with fixed ratios of certain dissolved constituents (Arnorsson, 2000). The group of silica mineral is usually ideal for geothermometry. Several silica geothermometers have been developed and the most important are shown below. These geothermometers have been developed by many individuals, but here information is taken from Arnorsson, 2000. For original references, the reader is referred to that source.

$$T = 1032/(4.69-LOG(S))-273.15, \tag{1}$$

$$T = 1309/(5.19-LOG(S))-273.15 \tag{2}$$

$$T^{a} = 1522/(5.75-LOG(S))-273.15 \tag{3}$$

$$T = -42.2+0.28831*S-3.6686*10^{-4}*(S)^{2}+3.1665*10^{-7}*(S^{)3}+77.03*LOG(S) \tag{4}$$

$$T^{a,b} = -53.5+0.11236*S-5.559*10^{-5}*(S)^{2}+1.772*10^{-8}*(S)^{3}+88.39*LOG(S) \tag{5}$$

$$T = -53.3+0.3659*S-5.3954*10^{-4}*(S)^{2}+5.5132*10^{-7}*(S)^{3}+74.36*LOG(S) \tag{6}$$

$$T^{a} = -66.9+0.1378*S-4.9727*10^{-7}*(S)^{2}+1.0468*10^{-8}*(S)^{3}+87.84*LOG(S) \tag{7}$$

$$T = 1112/(4.91-LOG(S))-273.15 \tag{8}$$

(1) Chalcedony, 0-250°C, Fournier, 1977; (2) Quartz, 25-250°C, Fournier, 1977; (3) Quartz, 25-250°C Fournier, 1977; (4) Quartz, 25-900°C, Fournier and Potter, 1982; (5) Quartz, Fournier and Potter, 1982; (6) Quartz, 0-350°C, Arnorsson et al, 1988a; (7) Quartz, 0-350°C, Arnorsson et al. 1988a; Chalcedony, 0-250°C Arnorsson et al, 1983b.

a: Silica concentrations in water initially in equilibrium with quartz after adiabatic boiling to 100°C.
b: As presented by Arnorsson (1985)
S: Silica concentration, mg/kg

The cation geothermometers are also presented as follows (Arnorsson, 2000):

$$T = 856/(0.857+LOG(Na/K))-273.15 \qquad (100\text{-}275°C) \tag{1}$$

$$T = 1217/(1.438+LOG(Na/K))-273.15 \tag{2}$$

$$T = 833/(0.55+LOG(Na/K))-273.1 \tag{3}$$

$$T = 933/(0.993+LOG(Na/K))-273.1 \qquad (25\text{-}250°C) \tag{4}$$

$$T = 1178/(1.47+LOG(Na/K))-273.15 \tag{5}$$

$T = 1390/(1.75+LOG(Na/K))-273.1$ (6)

$T^a = 733.6-770.551*LOG(Na/K)+378.189*(LOG(Na/K))^2-95.753*(LOG(Na/K))^3+9.544*(LOG(Na/K))^4$ (7)

$T^{ab} = 1647/(LOG(Na/K)+\beta*LOG(Ca^{0.5}/Na)+2.24)-273.15$ (8)

(1) Truesdell, 1976; (2) Fournier, 1979; (3) Tonani, 1980; (4)Arnorsson et al., 1983; (5) Nieva and Nieva, 1987; (6) Giggenbach, 1988; (7) Arnorsson, 1998.

a: values in molal ratio; b: TNaKCa

There are also several gas geothermometers in the literature, but most of them give over/sub-estimated values. The most reliable geothermometers are the ones which are in approximation of the reservoir temperature. In El Salvador (and others countries), the LHA-LCA geothermometer has been used and has given good results, as well as the D´Amore & Panichi geothermometer.

3. GEOLOGICAL SETTING

3.1 Lithology

The Chinameca geothermal area (Figure 1) is composed of a series of Quaternary volcanoes with lavas different from the Tertiary volcanoes. The most ancient lava is located in the area of Cerro La Luna, corresponding to fine dacites.

The stratigraphy of Chinameca is composed of the Cuscatlán Formation (Unit c2) with acid and intermediate-acid effusive rocks of Plio-Pleistocene age. The lavas of El Cerro Lolotique (porphyritic basalt), Cerro El Zope and Cerro Chambala in San Jorge also comprise Unit c3 of the Cuscatlán Formation, having basic-intermediate effusive rocks.

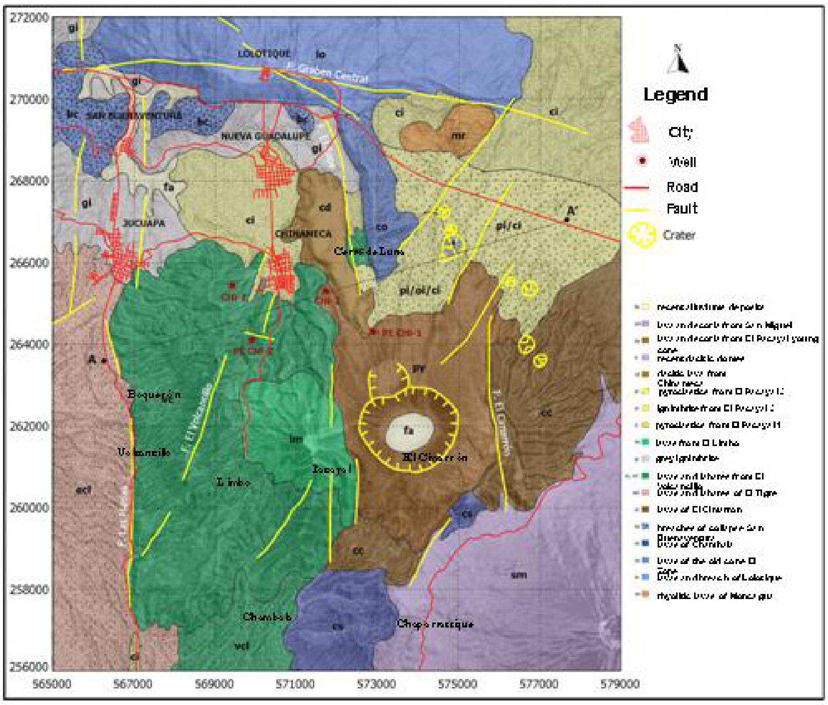

FIGURE 1: Geology of Chinameca system

El Volcancillo is an eroded volcano affected by tectonic processes and is made up of porphyritic pyroxene andesites, which are overlain by lavas of the El Limbo volcano. Several fumaroles are present along the lavas of Volcancillo such as Boqueron and La Viejona and some small fumaroles (Alsacia, Las Flores, Coban Alto and Silva). The lavas of El Volcancillo correspond to Unit s2 of the San Salvador Formation (Pleistocene age), which is composed of the intercalation of acid pyroclastic deposits and acid-basic effusive rocks. Cerro El Cimarrón also belongs to Unit s2.

Cerro El Limbo is found at the central part of the study area, in contact with the deposits of the Pacayal volcano and lavas of El Volcancillo. The lavas of Cerro El Limbo belong to Unit s5b of the San Salvador Formation.

The Pacayal volcano presents a crater of great dimension and is composed of lavas of varying compositions from dacite to porphyritic pyroxene andesite. The variation in composition of lavas could indicate a process of recent magmatic differentiation in a relatively short magmatic camera. This difference of materials can be observed at the base of the crater up to the higher part. The Pacayal lava is part of Unit s2 of the San Salvador Formation (Figure 1).

3.2 Structural geology

The tectonic of the area is produced by the subduction of the Cocos and the Carribean plates. Like most of the geothermal fields of the country, the study area is influenced by the predominant regional structures of the central graben, with a preferential E-W direction. There exist at least two systems of faulting in the area; the first system corresponds to the central graben with preferential E-W direction and the second is close to N-S direction that is well evident in the area. The N-S and NNW-SSE lineaments predominate the area of study, and correspond to Fault Las Marias (delimits the western part of the area), Fault El Cimarron (Pacayal-Cimarrón limit), the southern boundary of El Pacayal-El Limbo, Fault El Zope and three lineaments in the Cerro El Cimarron. The fumarole El Hervidero in the small village Las Mesas is located along Fault El Zope. Most of the structural data taken in the pyroclastic deposits that cover El Volcancillo and El Cimarron are related to this system (See Figure 1). It could be considered that the Pacayal volcano is along the fault system in this direction and is bounded by the East and West faults.

4. WATER GEOCHEMISTRY

The study area comprises 375 km^2 (Figure 2) and 58 samples of springs and domestic wells were collected, of which 36 have temperatures of 29°C. Two exploratory wells, CHI-1 and CHI-2, were drilled by CEL in 1978 and 1979. The development of the geothermal field of Chinameca was suspended by the civil war and restarted in 2005.

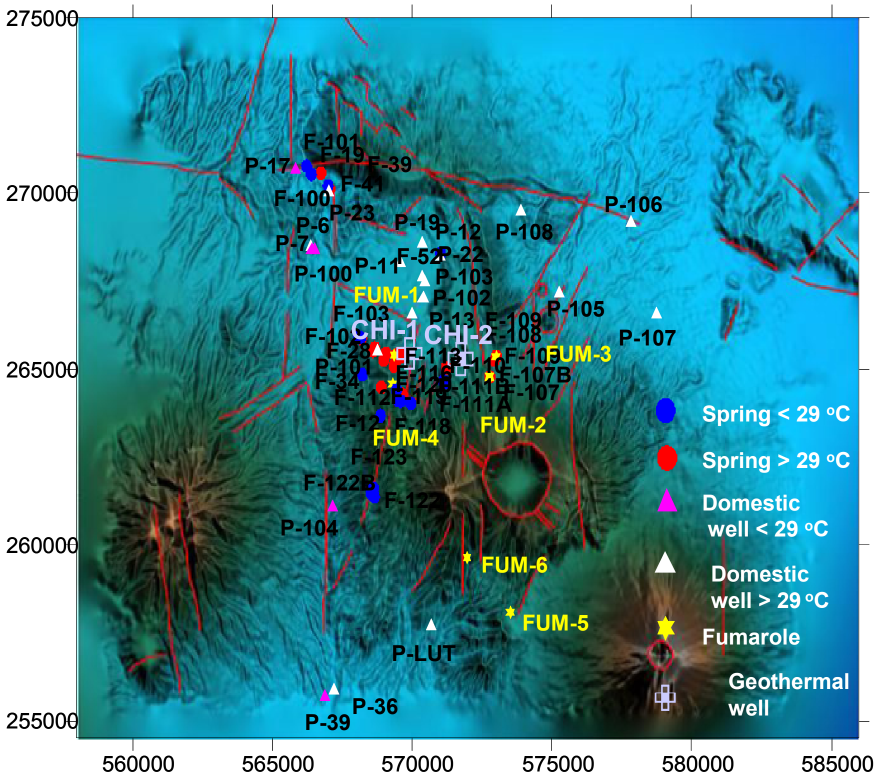

FIGURE 2: The study area of Chinameca

The temperature found in well CHI-1 was 160°C, whereas in well CHI-2 was 195°C. These temperatures do not agree with the expected calculated geothermometric temperatures in the reservoir. At the south-western part of the volcano El Pacayal, an exploratory well, P-Lut, was drilled by CEL in

1978. Sampling of this well was done in 1997 and the results were re-evaluated in this work. The chemical analyses and the isotopes of waters were carried out in the laboratory of geochemistry of La Geo de S.A. of C.V.

4.1 Water classification

Figure 3 shows the Piper diagram of the superficial waters of Chinameca. According to the figure, most of the samples of domestic wells and springs are calcium-magnesium-bicarbonate waters indicating its superficial character; some samples present a tendency to be sulphate waters, and these belong to springs located in fumarolic zones of Los Infiernillos and La Viejona, with temperatures of 95 to 100°C. The springs and domestic wells present changes in their composition due to the cationic interchange influenced by the temperature and the clay presence in the area. The results of the samples of well CHI-2 are sodium chloride waters, characteristic for geothermal waters.

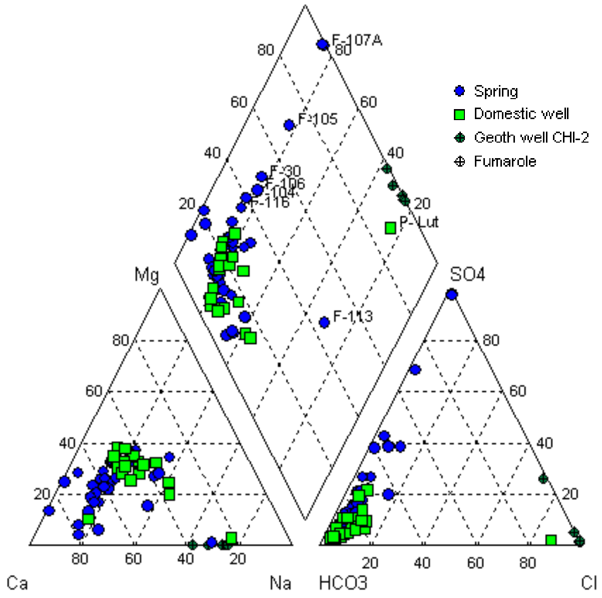

FIGURE 3: Piper diagram of Chinameca waters

In Figure 3, it can also be seen that the spring F-113 is of the sodium-calcium-bicarbonate-sulphate type showing characteristics of a spring with a certain geothermal interaction. This spring is located between the area of El Boqueron and La Viejona and has a temperature of 85°C. It does not present very saline characteristics; nevertheless it seems to have a water-bearing initial origin of a deep reservoir. Although it has a low anion and cation content, this type of spring is characteristic of a mixture of deep fluids that rise through the microfractures from a deep reservoir and eventually mixe with superficial waters (Giggenbach, 1988). This water is similar to the ones identified in the geothermal area of San Vicente (Matus, 2005) and in Chinameca (Martinez, 1979).

The domestic well, P-Lut, presents a sodium-calcium-chloride characteristic and presents a greater salinity than the other domestic wells, which could indicate that this well shows a mixture of superficial waters and geothermal waters located southwest of the volcano El Pacayal.

Springs F-105, F-106, F-107A, B, C, F-108A, B are sulphate waters and located in fumarolic areas of La Viejona to the west and the Los Hervideros to the east of the field. These waters are typically found at the higher part of the upflow zone of the hydrothermal system, where separation of gases and steam exists mainly boiling of the gas species (CO2 and H2S). Alternatively, separated steam can be condensed, at least partially, in underground or superficial waters to form waters warmed up by steam (Marini, 2004).

The Cl-SO_4-HCO_3 diagram in Figure 4 shows that the P-Lut well and well

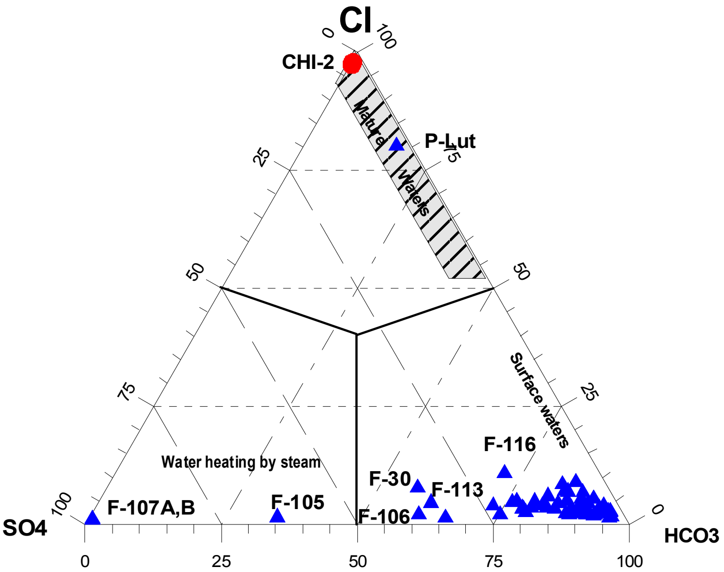

FIGURE 4: The Cl-SO_4-HCO_3triangular diagram of

CHI-2 are in an area of mature waters, which means that these waters have geothermal components. Spring F-113 is characterized as surface waters but with a tendency to be sulphate.

4.2 Stable isotopes

Figure 5 shows the isotopic composition of the surface waters of the Chinameca system; in this case no isotopic data of exploratory well CHI-1 are present.

Most of the samples are near the meteoric line, indicating that they are surface waters that have not been mixed with geothermal waters or that there exists a high dilution of the geothermal waters in the zone, since they do not present deviation with the meteoric line in oxygen-18 and do not show water-rock interaction or discharge temperature (ex. Ahuachapán and Berlin).

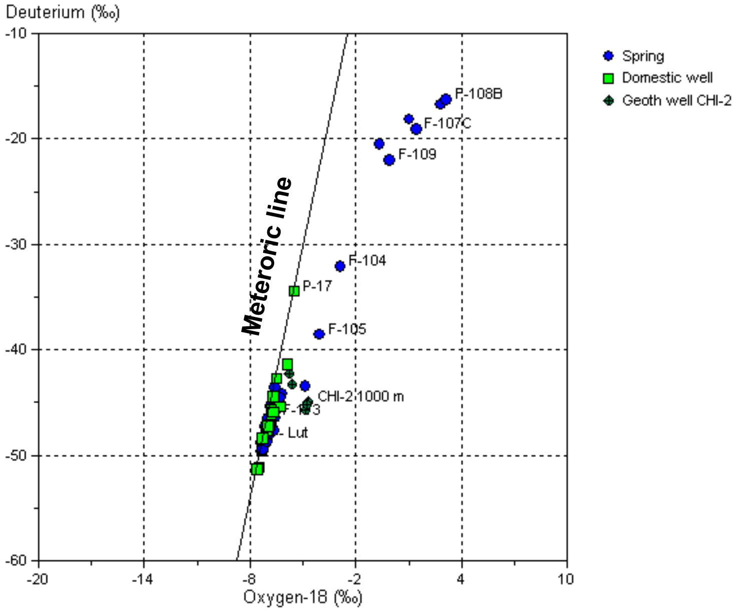

FIGURE 5: Isotopic composition of Chinameca system

Well CHI-2 shows a deviation with the meteoric line in oxygen-18 of 2.4$^{o}/_{oo}$ in the deep samples at 1,000, 1,500 and 1,700 m. The deviations with the meteoric line in oxygen -18 are less than the geothermal waters found in the fields of Ahuachapán, Berlin and San Vicente (greater of 3$^{o}/_{oo}$), which are probably due to a mixture with surface waters. The P-Lut well has an isotopic deficient composition in heavy isotopes (depleted) indicating a geothermal water mixture with surface water. Springs F-108, F-107 B and C and F-109 are the origin of the fumarole of Los Hervideros and show isotopic values more positive due to the intense evaporation that has occurred. Springs F-104 and F-105 lie along the area of fumarole La Viejona and they also present a line of evaporation.

4.3 Recharge of the system

In order to evaluate the recharge of the Chinameca system, a correlation of the isotopic values of waters of springs and domestic wells has been made with respect to elevation (see Figure 6). In all, 41 samples have been considered and with an r = 0.66 (the symbols in red represent the correlated samples). The equation obtained for the correlation of 41 samples is:

$$h = (- \delta^{2}H - 36.56)/0.0184$$

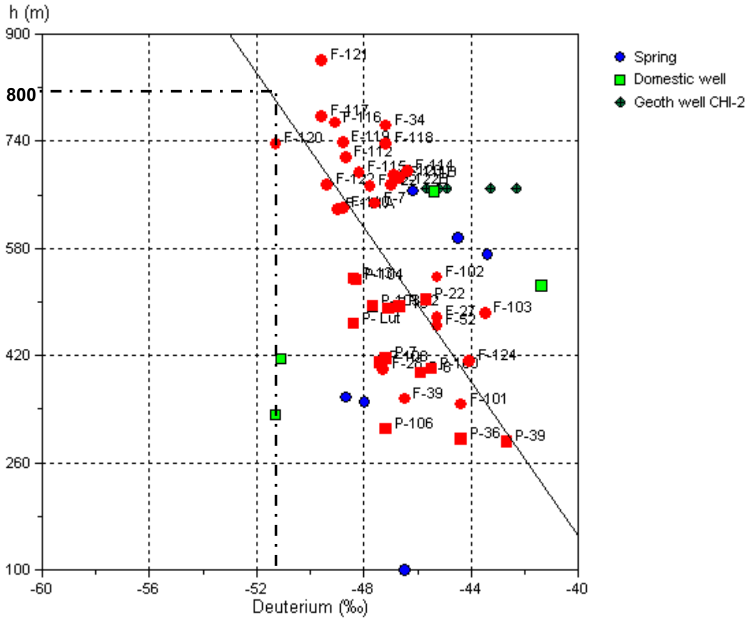

FIGURE 6: Deuterium vs. elevation, h, in the Chinameca system. r = 0.66, n = 41. The well CHI-2 is plotted in agreement of the altitude of the platform (669 m)

According to Figure 6, the recharge of surface waters in the volcanic system of Chinameca would be represented by waters similar to underground waters of the well P-107. This well is located at an elevation of 337 m in the north-eastern part of the area. However, calculation of the elevation of recharge from the isotopic composition would correspond to a higher value of 800 m, which is in agreement to that of the crater of the volcano El Pacayal, providing high permeability.

4.4 Water geothermometers

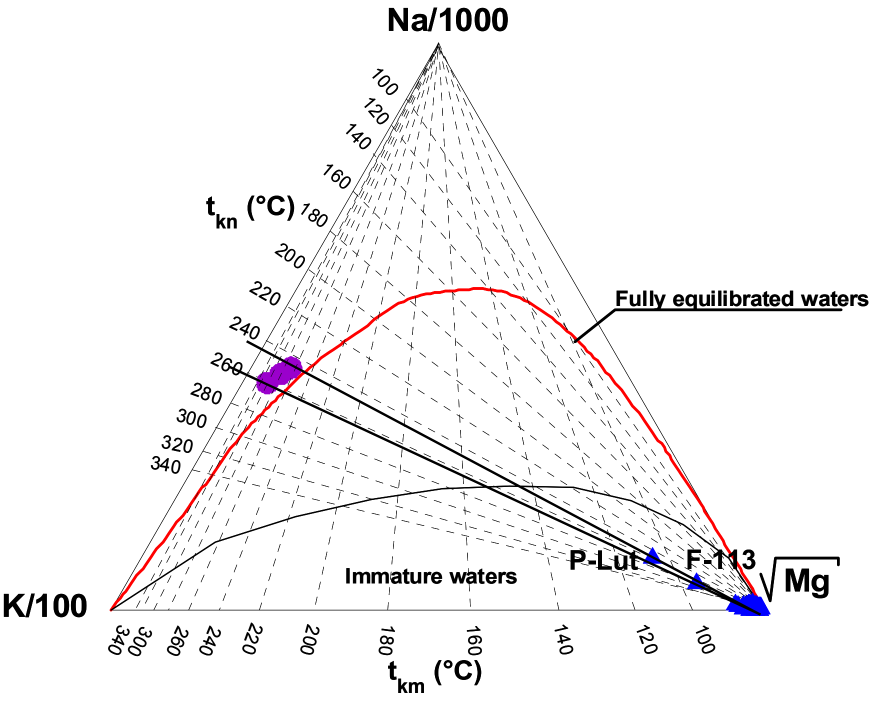

FIGURE 7: Giggenbach diagram for 2005 samples from Chinameca,

Figure 7 shows the Giggenbach diagram in 1988. It can be observed that most of surface water samples are in the corner of magnesium, indicating that high geothermal water influence does not exist on surface waters. Only spring F-113 and the P-Lut well are a little bit farther than the Mg corner, indicating a possible geothermal water component. However, Fournier (1991) indicated that care should be taken when the samples are in the zone of waters that are not equilibrated.

Nevertheless, in the geothermal systems of El Salvador (Ahuachapán, San Vicente, etc.), the surface waters with geothermal characteristics are very diluted, and the cationic geothermometers (e.g. Giggenbach, 1988) have given good results (Appendix I).

Well CHI-2 is in the area of equilibrated waters, thus, the obtained values of temperature are considered reliable. Therefore, the considered temperature indicated by spring F-113, the P-Lut well and well CHI-2 is 240 – 260°C, as indicated by the lines extrapolated towards equilibrated waters.

Table 1 and 2 present the results of the water geothermometer of SiO2, Na/K y Na-K-Ca.

TABLE 1: SiO_2 geothermometers

Site	Date	TChalF77	TQz F77	TQz F77i	TQz FP82	TQz FP82i	TQz Ar88	TQz Ar88i	TCh Ar83
		oC							
F-113	25/11/05	101.6	129.2	126.0	124.2	127.0	118.6	114.7	100.8
P-Lut	6/11/97	117.6	143.6	138.1	138.3	139.5	134.1	127.9	115.6
CHI-2 1000 m	3/9/06	144.1	167.1	157.6	161.6	159.5	159.6	149.2	139.7
CHI-2 1500 m	3/9/06	140.2	163.6	154.8	158.1	156.6	155.8	146.1	136.1
CHI-2 1700 m	3/9/06	136.5	160.4	152.1	154.9	153.8	152.2	143.1	132.8

TABLE 2: Cationic geothermometers

Site	Date	TNa/K Tr76	TNa/K F79	TNa/K Ton80	TNa/K Ar83	TNa/K Ar83	TNa/K Ni87	TNa/K Gig88	TNa/K Ar88	TNaKCa
		°C								
F-113	25/11/05	253.1	278.1	358.1	256.2	261.1	252.8	278.5	324.3	181.4
P-Lut	6/11/97	223.7	255.1	315.2	228.8	241.1	231.2	258.2	293.1	195.5
CHI-2 1000	3/9/06	207.4	242.1	291.9	213.5	229.7	218.9	246.6	275.9	208.1
CHI-2 1500	3/9/06	215.6	248.7	303.6	221.2	235.5	225.1	252.5	284.6	212.8
CHI-2 1700	3/9/06	226.5	257.3	319.3	231.4	243.1	233.3	260.2	296.1	217.6

The ranges of temperatures using silica geothermometers of spring F-113 are 100-129°C and those of the P-Lut well are 116-144°C. The temperatures for well CHI-2 are within the range of 133- 167°C, while the measured temperature is 195°C. These values are lower than the temperatures obtained by the cationic geothermometers, indicating a possible presence of original geothermal water which has undergone cooling and/or mixing with surface waters, and silica precipitation on its way (Arnorsson, 2000). Therefore, these geothermometers cannot be used to evaluate the conditions of the geothermal reservoir.

The cationic geothermometers present higher temperatures and quite great variations. However, this is an inherent condition of the geothermometers as the results for the different chemical and isotopic geothermometers vary for each well (Arnorsson, 2000).

If geothermometers provide similar results, it can be assumed that water-rock equilibrium is attained, hence the results are reliable. In Chinameca, water-rock equilibrium was assumed using the geothermometers Truesdell (1976), Fournier (1979), Arnorsson (1983), Nieva (1987), Giggenbach (1988) and Arnorsson (1998). The range of temperature of waters in well CHI-2 is 217-253°C, while spring F-113 and well P-Lut have average temperatures of 238.4- 278°C.

The geothermometer of Tonani (1980) give higher values. Waters from well CHI-2 have temperature values of 286-305°C, while spring F-113 and the domestic well P-Lut are 309- 337°C.

Taking into account the triangular Giggenbach diagram for Na-K-Mg (1988) with the geothermometers Na/K, the temperature considered is of the range 240-260°C, which is consistent with the values of gas geothermometers.

5. GASES

Six fumaroles with gas emanation were sampled: a) La Viejona fumarole (FUM-1) located northwest of El Pacayal and near the well CHI-1, b) Los Hervideros fumarole (FUM-2) located northeast of El Pacayal, c) Las Tablas fumarole (FUM-3), along the extension of the fault of the Los Hervideros, d) El Boquerón fumarole (FUM-4) located at the south-eastern part of La Viejona fumarole, 5) La Joya Verde fumarole (FUM-5) located south of the El Pacayal and 6) Chambala fumarole to the southwest of El Pacayal (FUM-6).

Figure 8 shows the geotemperatures of gases using the LHA-LCA diagram. All fumaroles lie near the line of equilibrium with the liquid, obtaining temperatures of 250-280°C. The La Joya fumarole is not in equilibrium and its

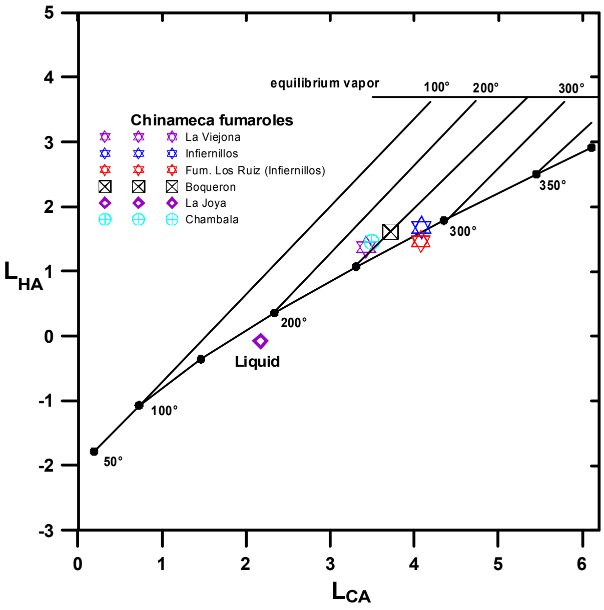

FIGURE 8: Gas geothermometer, $L_{H2/Ar}$-$L_{CO2/Ar}$

temperature is 150-190°C.

Since the geothermometers of gases sometimes indicate temperatures at higher depths, in the geothermal fields of Ahuachapán and San Vicente, this geothermometer presents values of 10-20°C higher than the temperature measured in geothermal wells, thus a smaller value would be expected in Chinameca than the measured ones using gas geothermometers.

Table 3 presents the results of the D´Amore & Panicchi geothermometer.

TABLE 3: Results of the D´Amore & Panicchi gas geothermometer for Chinameca

Fumarole	Date	T D&P
FUM-1	18/11/2005	288.3
FUM-2	22/11/2005	224.2
FUM-3	22/11/2005	214.0
FUM-4	24/11/2005	295.4
FUM-5	30/11/2005	223.1
FUM-6	06/12/2005	251.8

The results show that the temperatures are between 214-295°C, which are similar to values found with the LHA-LCA geothermometer.

6. CONCEPTUAL MODEL

In the Figure 9, the hydrogeochemical model of Chinameca is show. Here, the geothermometer temperature value of 240-260°C is used, based on the Giggenbach triangular diagram (1988).

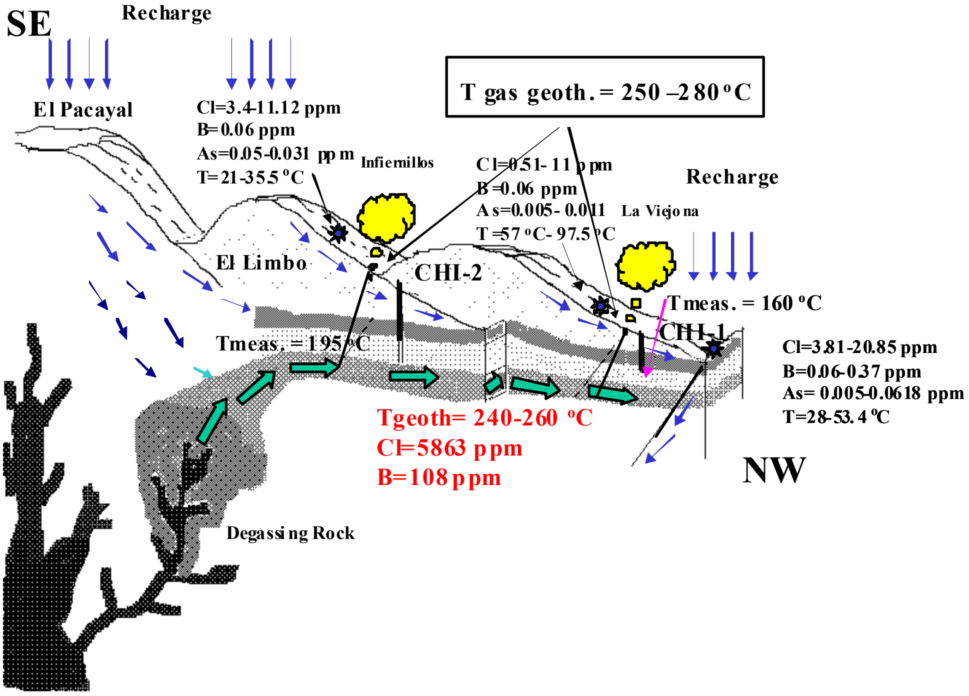

FIGURE 9: Hydrogeochemical model of Chinameca. The upflow model is suggested by MT studies

7. CONCLUSIONS

- Most of the domestic wells and springs present a high content of bicarbonate, indicating that they are meteoric waters. Most of the springs and wells present temperatures of 29°C due to heating by conduction and/or gases.

- Spring F-113 presents evidence of mixing with geothermal water. The value of 85°C is possibly a mixture of deep fluids that rises through microfractures reaching surface waters.

- Well P-Lut, located southwest of the Pacayal volcano, has a meteoric mixture of water and geothermal water.

- The isotopic composition of well CHI-2 presents a deviation in oxygen-18 of approximately $2.4^{o}/_{oo}$ indicating that interaction between water and rock has occurred, similar to other geothermal fields of El Salvador, indicating possible high temperatures in the reservoir.

- The recharge of the geothermal system is assumed to be at the southern part of the volcanic complex to an elevation of 800 m and also the outflow zone at the northern part of Chinameca near the central graben.

- The Giggenbach and Na/K geothermometers indicate temperatures of approximately 240-260°C while the LHA-LCA gas geothermometers give temperatures of 250-280°C.

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APPENDIX I: Result of the Giggenbach diagram for geothermal waters from El Salvador

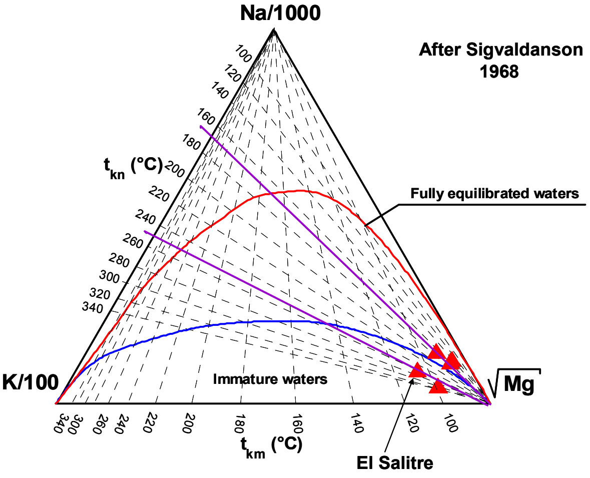

FIGURE 1: Plot of the El Salitre spring with data of 1968, Ahuachapan (after Sigvaldanson and Cuellar, 1970)

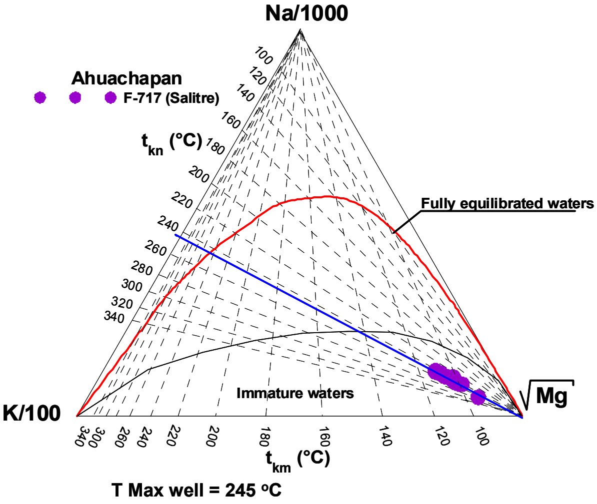

FIGURE 2: El Salitre spring with time

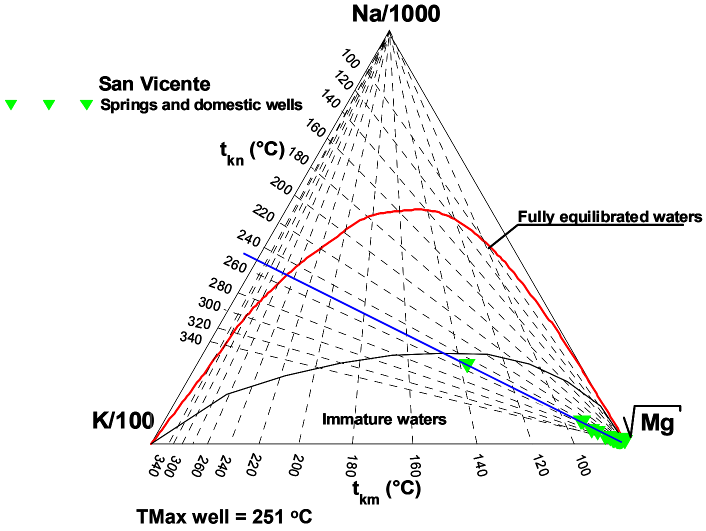

FIGURE 3: Surface waters from the San Vicente system

APPENDIX II: Data from the Chinameca geothermal system

Sitio	Fecha	x	y	Tmx	Ph	Tenv	Na	K	Ca	Mg	Li	Cl	SO4	NO3	HCO3	SiO2	B	Cond	Ox-18	Deut
		m	m	°C		°C	ppm											uS/cm	°/∞	
P-17	15/11/05	565817	270703	25.5	6.56	26.8	8.7	5.1	25.4	12.46	0.05	13.97	13.4	3.99	138.16	108.8	0.06	285.1	-5.5	-34.4
F-100	15/11/05	565817	270703	25.5	6.56	26.9	17.8	5.9	25.6	12	0.05	4.02	10.39	10.79	179.02	94.6	0.06	315.9	-6.8	-46.5
F-101	15/11/05	566405	270539	28.7	6.88	26.6	13.6	5.2	22.3	12.25	0.05	3.81	11.53	13.47	156.91	103.9	0.06	287.0	-6.5	-44.4
F-19	15/11/05	566227	270769	28.6	6.75	27.9	22.3	6.8	22.4	9.49	0.05	2.71	5.55	4.1	182.87	98.4	0.07	293.8	-7.1	-48.0
F-23	15/11/05	566743	270572	32.2	7.09	29.8	24	7.5	25.7	10.7	0.05	4.96	9.18	9.39	192.86	96.9	0.06	333.4	-7.0	-48.0
F-39	15/11/05	567001	270207	29.8	7.22	30.6	23.8	7.5	16.9	12.01	0.05	5.83	7.42	8.5	194.56	94.8	0.06	333.1	-7.0	-46.5
F-41	15/11/05	567063	270108	31.1	7.02	30.8	24.5	7.1	22.4	10.35	0.05	4.7	7.93	8.36	186.6	94.9	0.06	317.2	-7.1	-48.7
P-6	16/11/05	566391	268516	30.4	7.72	29.3	12.2	4.4	24.4	9.58	0.05	3.79	4.37	16.49	150.32	99.7	0.06	272.3	-6.7	-45.9
P-7	16/11/05	566391	268516	26	6.73	23.8	17.9	6	53.3	22.27	0.05	18.11	20.85	109.95	214.14	98	0.06	570.0	-7.0	-47.2
P-100	16/11/05	566513	268439	27	6.75	27.3	12.3	4.4	32.1	12.49	0.05	9.28	16.33	21.76	157.91	95.2	0.06	334.9	-6.6	-45.5
F-28	16/11/05	568195	265871	42	7.4	31.3	14.7	4.1	45.6	10.5	0.05	6.89	15.76	24.69	188.07	99.2	0.06	371.5	-6.9	-47.3
F-102	16/11/05	566168	265894	27.2	7.39	28	15.3	4	41.5	10.47	0.05	7.14	15.81	17.68	183.55	107.3	0.06	361.4	-6.8	-45.3
F-103	16/11/05	568101	265924	28.3	6.93	28.3	18.3	3.7	52.7	13.88	0.05	9.2	16.51	2.42	246.14	103.5	0.06	419.1	-6.6	-43.5
F-27	17/11/05	569576	265333	53.4	6.59	36.2	14.3	3.3	44.7	7.07	0.05	5.71	29.87	44.05	131.42	103.4	0.06	356.3	-6.7	-45.3
P-101	17/11/05	568769	265562	36.2	7.38	33.1	13.4	6	48.7	4.25	0.05	8.03	30.16	26.58	126.54	81	0.06	351.3	-6.3	-45.4
F-30	17/11/05	569071	265455	32	7.16	31.1	19.5	2.6	70.2	10.69	0.05	16.78	75.56	88.27	123.77	87.4	0.06	535.9	-6.3	-44.5
F-7	17/11/05	568671	265602	33	6.84	31.2	15.3	4.9	59.3	6.72	0.05	6.8	37.21	38.17	165.37	83.8	0.06	435.6	-6.7	-47.6
F-104	18/11/05	569410	265390	33.4	7.35	15.9	8.9	3.9	41.1	2.57	0.05	2.25	53.63	0.63	106.73	64.2	0.06	289.9	-2.9	-32.1
F-105	18/11/05	569411	265390	92	8.25	16	6.7	3.6	27.8	0.91	0.05	1.43	59.24	0	31.95	62.4	0.06	216.9	-4.1	-38.5
F-106	22/11/05	569556	265463	88	6.99	22.5	10.1	4.5	30.6	7.11	0.05	2.45	42.17	39.21	67.7	76.3	0.06	280.9	-4.9	-43.4
F-107A	22/11/05	572781	264780	97.5	5.63	16.1	5.4	7.2	19.8	5.22	0.05	1.28	118.23	0.15	1	151.3	0.09	283.1	-0.7	-20.5
F-107B	22/11/05	572782	264781	96	6.31	37.3	9.2	4.9	34.1	10.41	0.05	1.48	121.75	0.78	1	38.5	0.06	281.9	1.0	-18.1
F-107C	22/11/05	572783	264781	96	5.3	25.5	9.6	8.3	61.7	18.69	0.05				1	58.9	0.06	712.8	1.4	-19.1
F-108A	23/11/05	573019	265367	62.8	5.85	23.3	0.1	0.9	7.3	1.48	0.05	0.51	1.93	15.83	12.02	29.2	0.06	68.4	2.8	-16.7
F-108B	23/11/05	573019	265370	75.7	5.63	23.1	0.4	1.6	5.6	1.43	0.05	0.52	1.93	13.05	13.5	33.1	0.06	62.4	3.1	-16.3
F-109	23/11/05	572954	265258	57.7	7.09	22.8	0.1	1.9	8.9	0.85	0.05	0.6	1.85	6.24	24.51	43.5	0.06	65.4	-0.1	-22.0
F-110	23/11/05	571224	265037	29.8	6.93	23.1	14.9	4.9	35.7	10.64	0.05	10.96	7.57	12.12	182.66	83.5	0.06	345.0	-7.2	-48.8
F-111A	23/11/05	571119	264662	26.6	7.08	23.3	16.7	5.1	36.8	14.01	0.05	5.18	20.32	18.94	190.53	89	0.06	378.2	-7.3	-49.0
F-111B	23/11/05	571207	264624	23.6	6.42	23	21.1	5.6	31.8	14.11	0.05	7.14	41.24	57.62	130.33	80.1	0.06	404.0	-7.0	-46.7
F-112	24/11/05	568914	264485	29.2	7.5	22.6	9.5	3	42.6	9.46	0.05	7.1	13.39	16.31	176.87	70.6	0.06	345.7	-7.4	-48.7
F-113	25/11/05	569351	265091	82	8.76	21.8	25.3	4.3	9.7	0.22	0.05	3.69	27.42	11.77	49.1	86.4	0.06	209.3	-6.7	-46.2
F-114	25/11/05	568986	265251	57.5	7.69	21.2	12.3	5.4	32.7	1.69	0.05	5.61	22.66	29.91	90.5	94.3	0.06	273.3	-6.6	-46.4
F-115	25/11/05	568604	265514	37.5	7.05	21.7	15.8	4.5	58.5	11.21	0.05	6.61	44.53	22.76	200.4	92.1	0.06	451.3	-7.0	-48.2
F-116	25/11/05	569443	264410	27.5	6.98	23.2	12.4	1.1	39.1	14.63	0.05	20.05	32.22	28.81	131.71	96.1	0.06	381.5	-7.2	-49.1
F-34	25/11/05	568235	264840	27	6.74	22	11.8	3.2	32	13.53	0.05	7.98	19.47	21.11	150.47	97.6	0.06	330.7	-7.2	-47.2
P-13	28/11/05	569996	266618	37.8	6.73	36.3	21.9	7.2	45.9	15.56	0.05	14.44	28.53	35.98	197.59	103.5	0.06	451.6	-7.3	-48.4
P-102	28/11/05	570394	267062	26.1	7.84	27.5	19.4	6.7	47.1	17.04	0.05	12.9	14.48	39.29	207.66	100.2	0.06	442.9	-5.9	-41.4
P-22	28/11/05	570388	267668	24.3	7.66	25.5	18.2	3.9	29.7	9.35	0.05	4.84	3.56	12.46	160.76	92.2	0.06	290.5	-6.8	-45.7
P-12	28/11/05	569602	268058	29.5	6.59	29.1	15.2	2.4	32.1	13.43	0.05	3.8	10.79	19.78	179.2	97.5	0.06	339.7	-6.8	-46.7
F. 52	28/11/05	569487	264122	27	6.99	27.2	14.6	2.2	20	7.73	0.05	2.9	13.47	7.52	118.66	77.7	0.06	255.1	-6.9	-45.3
F-117	29/11/05	569487	264122	25.4	6.41	27.3	11.8	1.8	27.2	10.18	0.05	7.38	23.01	18.54	122.49	91.7	0.06	292.4	-7.4	-49.6
F-118	29/11/05	569960	264020	21.3	7.11	25.9	9.3	3.1	17	8.23	0.05	5.27	6.02	5.52	104.4	88.5	0.06	223.6	-7.2	-47.2
F-119	29/11/05	569597	264092	28.2	6.64	28.6	14.9	3.1	40.2	9.13	0.05	6.01	16.39	9.21	192.69	82.3	0.06	358.8	-7.4	-48.8
F-120	29/11/05	569658	264282	35.5	6.7	33.2	28.7	3.2	31.6	6.33	0.05	5.1	21.77	6.36	181.55	64	0.06	347.2	-7.6	-51.3
F-121	29/11/05	568879	263682	24.7	6.41	25	9.7	1.6	15.3	6.96	0.05	3.4	7.41	5.12	97.06	93	0.06	202.5	-7.3	-49.6
P-12	29/11/05	571003	268259	38.4	7.05	37.9	23.3	4.3	17.2	5.65	0.05	3.13	12.06	11.53	123.11	113.7	0.06	266.4	-7.1	-47.7
P-103	29/11/05	570475	267523	30.6	6.86	31.2	16.8	2.4	23.2	9.14	0.05	6.16	4.32	20.38	143.68	95.6	0.06	281.8	-7.0	-47.7
F-122	30/11/05	570456	265051	26	7.1	21.5	13.6	2.6	25.7	12.75	0.05	4.74	3.77	15.34	169.9	95.8	0.06	296.5	-7.3	-49.4
P-104	1/12/05	567181	261110	27.8	7.84	30.3	15.7	3.8	22.9	10.8	0.05	4.7	4.1	12.52	156.97	90.8	0.06	279.5	-7.3	-48.3
P-39	1/12/05	566899	255741	22.2	6.88	29	11.3	3.5	25.2	12.96	0.05	5.78	15.36	13.43	148.83	92.4	0.06	295.9	-6.5	-42.7
P-36	1/12/05	567228	255908	33	6.93	31.4	19.1	3.7	24.5	11.45	0.05	5.55	25.95	31.12	127.85	100.8	0.06	319.7	-6.7	-44.4
F-122	7/12/05	568654	261372	23.8	6.58	23.8	9.9	1.3	29.7	11.26	0.05	11.2	12.59	15.79	136.76	82.8	0.06	295.9	-7.1	-47.8
F-122B	7/12/05	568540	261460	22	6.39	23.6	9.7	3.3	31.8	8.7	0.05	4.52	12	12.5	142.38	81.6	0.06	271.7	-7.1	-47.0
F-123	7/12/05	568618	261611	24	7.45	23.7	12.3	1.4	35	13.24	0.05	7.14	24.99	29.36	146.77	85.8	0.06	342.9	-7.1	-46.9
P-105	7/12/05	575269	267199	35.2	7.28	27.6	32.9	5.8	24.3	10.51	0.05	11.48	8.23	10.28	192.53	105.1	0.15	353.2	-7.5	-51.1
P-106	7/12/05	577850	269198	29.2	6.63	27.6	16	5.5	28.7	13.68	0.05	13.86	8.34	60.24	132.48	101.4	0.06	354.1	-7.0	-47.2
P-107	7/12/05	578736	266595	33.7	6.69	27.9	37.1	8.1	35.8	19.75	0.05	21.39	16.19	7.62	279.01	108.4	0.37	497.7	-7.6	-51.3
P-108	7/12/05	573902	269535	31.7	6.71	27.5	11.5	3.5	19.5	9.68	0.05	2.47	3.42	7.79	138.84	102.1	0.06	253.5	-7.0	-47.4
F-124	8/12/05	569443	265345	37.6	7.24	21.4	19.2	4.4	82.1	14	0.05	7.52	83.98	10.15	277.89	88.2	0.06	576.9	-6.2	-44.1
P-19	6/12/05	570378	268624	32.5	6.94	27	16.8	3.3	23.3	8.88	0.05	5.16	5.75	14.31	140.67	96.9	0.06	264.3	-6.9	-47.1
P-Lut	6/11/97	570691	257756	45	7.65		285.2	38.84	71.72	5.951		565	18.7				10.34		-7.3	-48.4

SITE	DATE	Depht	T	pH	Na	K	Ca	Mg	Li	Cl	SO4	HCO3	SiO2	B	Cond	Ox-18	Deut
		m	°C		ppm										uS/cm	°/oo	
CHI-2	03/09/2006	1000	37.5	7.99	2856.8	340.2	904.3	0.1656	6.45	6336	121.62	15.42	164.7	116.6	17810	-4.7	-44.9
CHI-2	03/09/2006	1500	33.5	8.07	2771.4	353.5	813.9	0.1126	6.25	5935	128.1	15.75	156	113.2	17180	-4.9	-45.7
CHI-2	03/09/2006	1700	25.2	8.28	2457.7	342.3	687.4	0.0546	5.76	5319	125.87	15.58	148.1	95.6	15430	-4.8	-45.2