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Geochemical Characteristics of Reservoir Fluids in the Las Tres Virgenes, BCS, Mexico

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ABSTRACT

The liquid dominated Las Tres Vírgenes geothermal reservoir produces brines of Na-Cl type. The reservoir temperature is 280ºC and the fluid is in equilibrium with reservoir rocks. There is a good agreement in the estimated temperature from the composition of gaseous and aqueous species. The chemical composition of gaseous species is similar to most of the geothermal reservoirs in Mexico. In wells Lv-1 and Lv-3, the gas content is less than 1% by weight. The CO_2 is >95% by weight of the total dissolved gases. Thus, at 280°C, the reservoir gases are also in equilibrium with the liquid phase. The isotopic composition of the wells presents enrichment in $\delta^{18}O$, typical characteristic of geothermal origin fluids. The springs in the region present different isotopic and geochemical characteristics. For example, El Azufre (M1) and Agua Agria (M3) have acid-sulfate character, which is related to geothermal zones where the vapor absorption and H_2S oxidation are the dominating processes. The isotopic composition of these springs has been changed by evaporation. The other springs do not show any signature of geochemical influence. The isotopic compositions of these springs are closed on the meteoric water line. Their water is saline and contains exchangeable sodium resulting in the waters that are not suitable for even agricultural usages.

1. INTRODUCTION

The Las Tres Vírgenes geothermal field is located on the Baja peninsula, in the northern part of Baja California Sur (BCS) State, between 112° 20´ - 112° 40´ longitudes and 27° 25´- 27° 36´ latitudes (Fig.1). Its name ("Three Virgins" in English) comes from three N-S aligned volcanoes, La Vírgen, El Azufre and El Viejo. Santa Rosalia and San Ignacio, adjacent towns, are located 35 km to the SE and 45 km to the SW, respectively. The field extends over a 57 km^2 area at an average elevation of 720 m above sea level (Quijano and Gutierrez 2003).

In 1982, a pre-feasibility study geothermal project was initiated by Comisión Federal de Electricidad (CEF) (Ballina and Herrera 1984, Lira et al. 1984, Quijano 1984). Results supported the idea of drilling the first exploratory well Lv-2 in 1988 (López 1998). Subsequent studies (Tello 1988, Vargas and Garduño 1988, Bigurra 1989, López et al. 1989) improved the understanding of geothermal system and encouraged the continuation of efforts towards the deep exploration of the reservoir. The second stage studies of structural geology of the hydrothermal system were carried out to optimize the location of new wells (Tovar 1989, Gutierrez 1990, Viggiano 1992, López et al. 1993, Bigurra 1998, Garcia and Gonzalez 1998). Presently, there are four production wells and three injection wells. Recently, CFE performed a regional geochemical study to characterize the properties of fluids, produced by the deep wells and thermal springs located within and surround of the field (Tello 1996, 1998, Gonzalez et al. 2001, Portugal et al. 2000).

The first power plant came in operation in July, 2001. At present, there are two condensing turbines 5 MW each. In 2003, total steam production was 0.31 millions tones with an average rate of 35 t/h. Total production of electric energy was 32.8 GWh. The electricity was distributed to the nearby localities which were isolated from the Mexican national electrical grid (Gutierrez and Quijano 2005).

The study presents a chemical and isotopic characterization of surface springs and reservoir fluids in order to identify the origin of the reservoir fluids in the Las Tres Vírgenes geothermal field.

2. GEOLOGICAL SETTINGS

The study area forms a part of a tectonically active extensional area: NW-SE trending faulting, which is a lateral extension of the San Andreas fault system, initiated at the end of Miocene (10 m.a.). The geothermal field lies within a volcanic complex composed of the three volcanoes –La Vírgen, El Azufre and El Viejo- inside a buffer zone for the El Viscaíno Biosphere Reserve.

From the structural viewpoint, the Las Tres Vírgenes geothermal field is located within a NW-SE trending Pliocene to Quaternary depression (Santa Rosalia Basin) that constitutes the western limit of the deformation zone related to the opening of the Gulf of California. In Baja California, a Pliocene-Quaternary extensional tectonic regime with NE-SW and NW-SE structural trends triggered the formation of three important volcanic centers: La Reforma, El Aguajito, and Las Tres Vírgenes. This deformation formed a regional NW-SE striking fault system which extends to the Gulf of California coast with structural blocks tilted to SW (López et al. 1995).

The geothermal reservoir heat source is related to the magma chamber of La Vírgen volcano, the youngest of the complex in the southern part of the field. Geothermal fluids are contained in intrusive rocks (granodiorites) with low secondary permeability. These rocks are the part of the regional intrusive basement of California Batholith, a post-Cretaceous granodioritic intrusion dated at 91 to 84 m.a. and at depths of 900 to 1000 m (López et al. 1993). Volcanic-sedimentary rocks overlie the basement. At depth, secondary minerals occur as a replacement of primary phases. Veining or direct deposition is not very abundant.

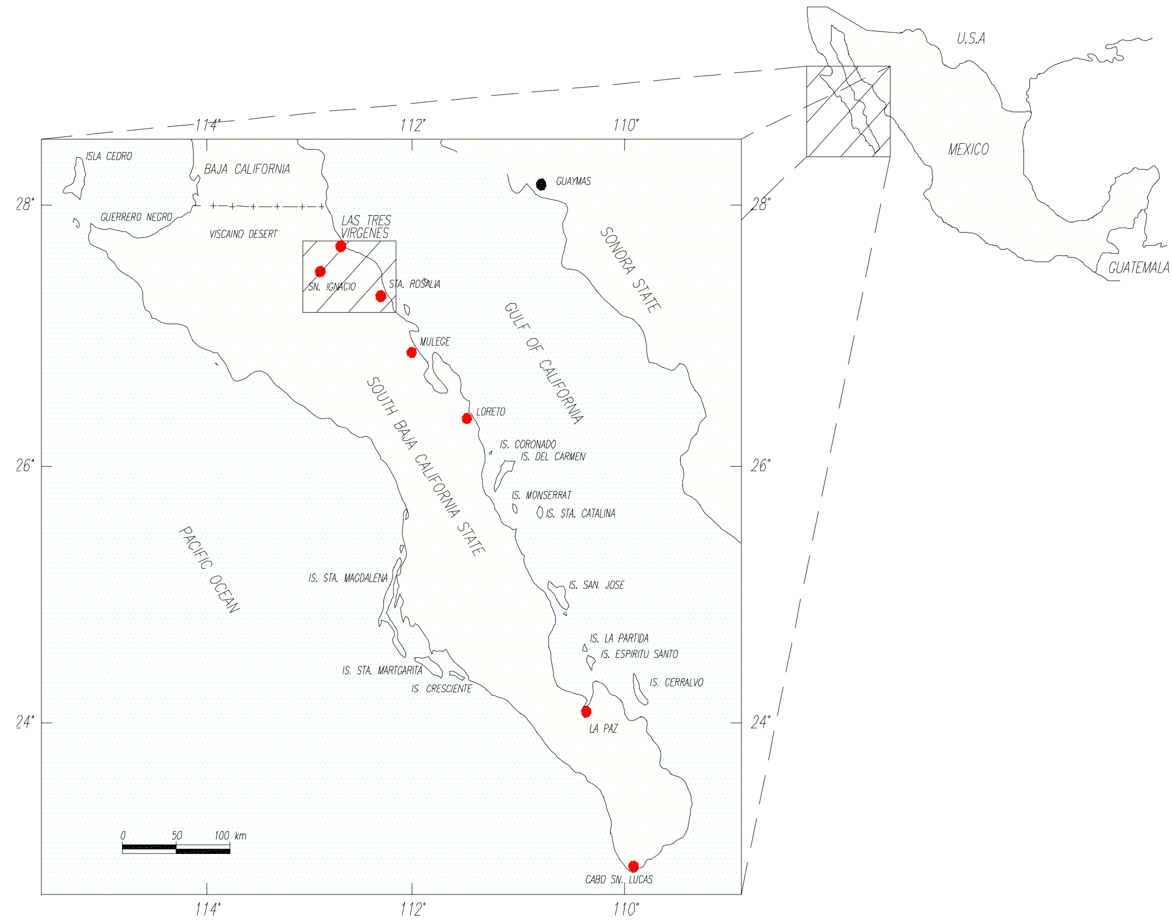

Figure 1: Location map of the Las Tres Vírgenes geothermal field in the state of Baja California Sur, Mexico.

There are few narrow veins of quartz and calcite. The vein minerals in the subsurface rocks include quartz, calcite, and clorite, with varying proportions of adularia, illite, sphenepyrite, hematite, wairakite, and anhydrite (Viggiano and Gutierrez 2000).

3. FIELD WORK AND LABORATORY ANALYSIS

Water samples for chemical and isotopic analyses and gas samples for chemical analyses were collected from wells and natural manifestations, using the procedure of Giggenbach and Goguel (1989). Chemical data refer to the period 1995-2003, while isotopic determinations were carried out only on the samples taken in two field trips during 1996-1997. Complete gas analyses (CO_2, H_2S, N_2, CH_4, H_2, Ar, He, O_2) are available for 8 samples (5 from production wells, 2 from El Azufre and 1 from Agua Agria) collected during the 1996 survey.

Chemical analyses of water samples were carried out in the laboratories of Morelia and Las Tres Vírgenes geothermal field within a few hours of sampling. Cations (Na, K, Ca, Mg) were determined by atomic absorption spectrometry (AAS), Cl-by volumetric titration and SO_4-by colorimetric methods (UV-Vis spectrometry), SiO_2 in low concentrations-by colorimetric methods and in high concentrations-by AAS, and, finally, HCO_3 was determined by acid-base titration. The pH and conductivity were determined in the laboratories.

Gas samples were collected in the evacuated 300 ml bottles containing 75 ml of NaOH 4N. The analyses of major constituents (CO_2, H_2S, NH_3) were made by wet chemistry, while minor constituents (N_2, CH_4, H_2, Ar, He, O_2) by gas chromatography. The chemical analyses of gas samples were performed at the CFE laboratories in Morelia and in the geothermal field.

The hydrogen and oxygen isotopic composition (δD and $\delta^{18}O$ values, in ‰ vs. V-SMOW) of water and steam samples were determined in the Isotope Hydrology Laboratory, IAEA, Vienna and in the laboratory of Instituto de Investigaciones Eléctricas, Cuernavaca, Mexico by reaction of water with metallic zinc (Kendall and Coplen 1985), and CO_2-H_2O equilibration (Epstein and Mayeda 1953) methods, respectively.

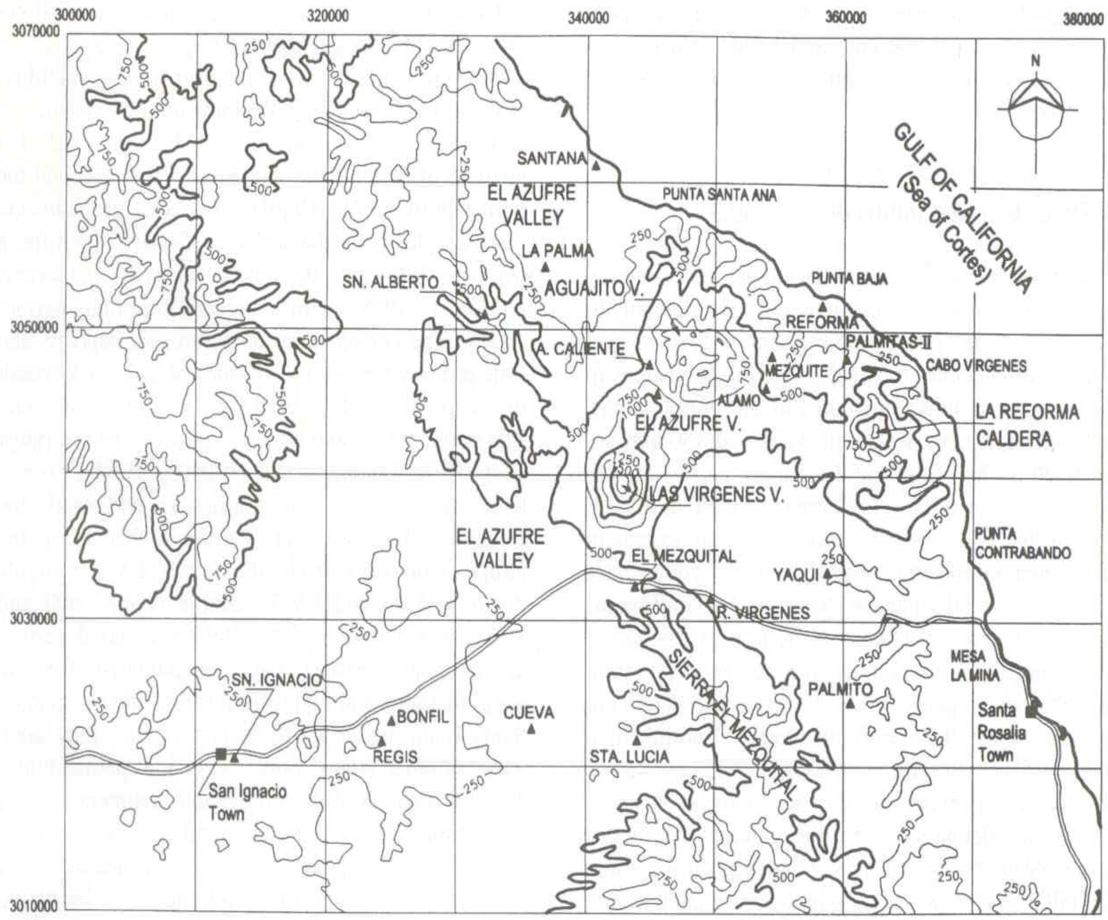

Figure 2: Location of natural manifestations in the Las Tres Vírgenes geothermal field.

4. CHEMICAL COMPOSITION OF THE WATERS

The chemical compositions of springs and domestic wells are given in Table 1. Figure 2 shows the location of sampling points. Table 2 gives the data for the wells. Tello (1988) reported the first results of geochemical study.

Figure 3 shows the classification of waters from the springs and domestics wells based on their chemical composition of Cl, HCO3 and SO4 (Giggenbach, 1991). Springs and domestics wells can be grouped in three water types: (a) cold water from streams and shallow aquifers, (b) alkaline pH thermal water, and (c) sulfate-rich acid thermal water. The evolution of these different water types is closely related to the morphology and faults in the region. The sulfate-rich acid manifestations are found along the slopes of El Azufre volcano at high elevation (>750 masl). These sulfate manifestations comprise steaming ground and fumarolic emissions. The alkaline pH thermal waters emerge between Aguajito volcano and Reforma Caldera, along a NE-SW trending at elevation <500 masl.

The measured concentrations in the liquid phase produced by the geothermal wells have been corrected for steam loss, assuming single-step adiabatic boiling between the undisturbed reservoir and wellhead. Table 3 gives the corrected gas concentrations, while the corrected water concentrations are given in Table 4.

The aquifer water from the production wells has high chloride content (5235-6734 mg/l). The samples cluster around the point representing 100% Cl and are independent of temperature and the geographic location of wells (Fig. 3). The SO4 and HCO3 concentrations are relatively low and similar (42-99 and 68-140 mg/l, respectively, given in Table 4). Na is the most abundant cation (2863-3929 mg/l), followed by K (469-644 mg/l), whereas Mg is present in traces only (0.07-0.28 mg/l). pH is neutral or weak alkaline (values ranging from 7.2 to 8.0, measured at 20°C in samples collected at the wellhead, Table 2). More detailed information on the chemistry of deep reservoir fluid was obtained by combining analyses of liquid and steam samples. The speciation calculations were carried out by using WATCH (Arnorrson et al. 1983). The fluids from geothermal wells can be considered as a chemically uniform family of waters. All the wells produce brines of Na-Cl type, a characteristic of brines of geothermal origin.

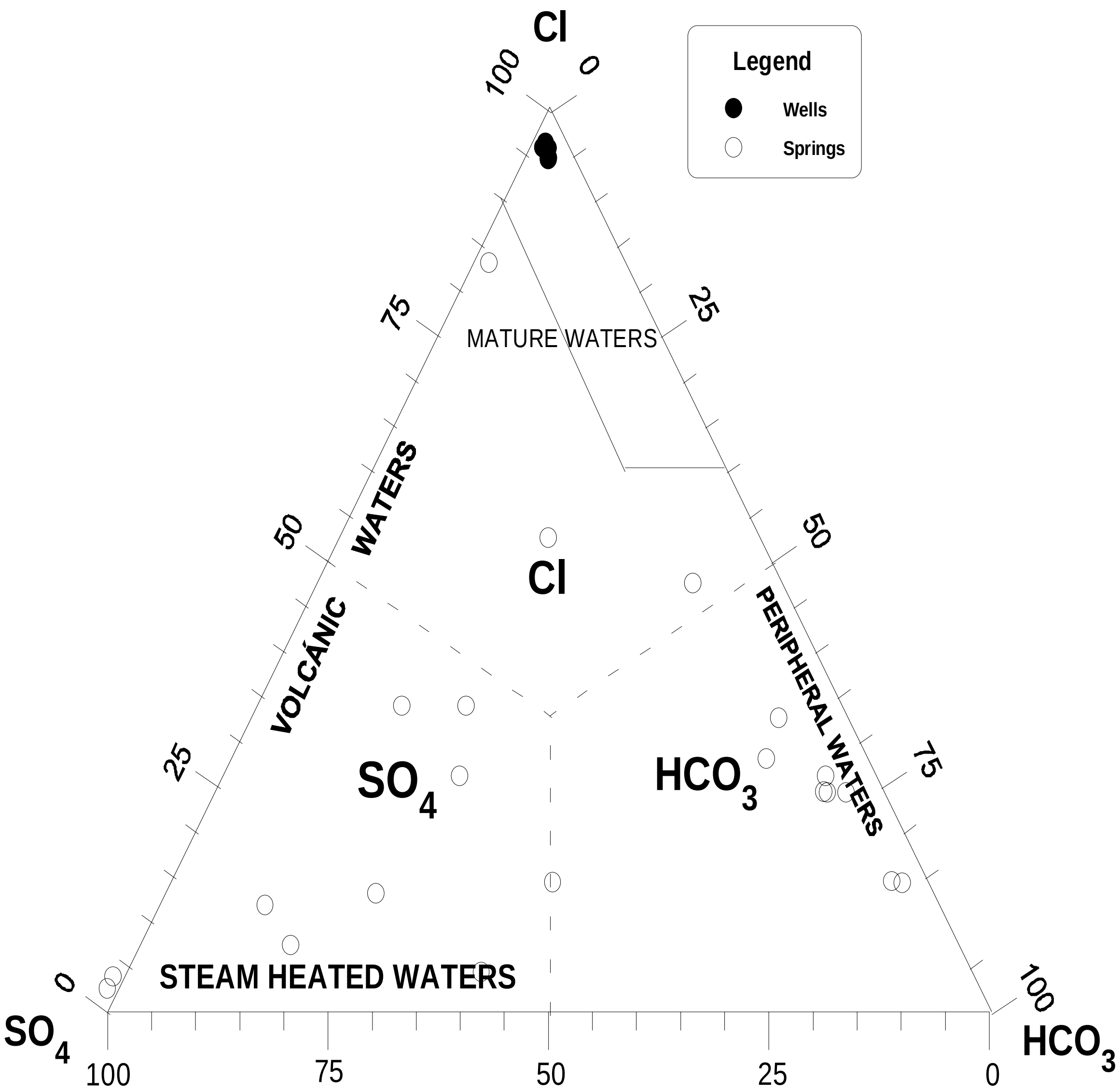

Figure 3: Classification of surface and deep waters and their origin. The concentrations are used in mg/kg.

Since 1995, CFE has monitored the water composition of 21 hot springs within the boundaries of the geothermal system in order to predict a correlation with the reservoir fluids. The chemical monitoring also served in the study of the environmental impact due to the exploitation of the geothermal resources and the injection of spent brines into the reservoir.

The springs El Azufre (M1) and Agua Agria (M3) in the NW part of the field are SO_4-type and contain low chloride 6 and 13.6 mg/l, respectively. According to the classification from Fig. 3, these are the steam heated waters and are located in the areas where steam, resulting from boiling of deep water at high temperatures, rises to the surface. The oxidation of H_2S to sulfate ion occurs near the surface. The concentration of sulfate of these springs varies from 2444 mg/l (El Azufre) to 850 mg/l (Agua Agria).

The waters from Agua Caliente, Santana, La Palma and Sn. Alberto are located in the NW-part but mainly in the area of the Las Tres Vírgenes volcanic complex and the Aguajito complex. These waters can be explained as a mixture of geothermal steam with groundwater resulting in diluted waters of neutral or slightly alkaline pH. The waters derived from El Mezquite (M17) and El Tule (M13) present a Na-Cl chemical character. The concentration of Cl is 405 (M13) and 453 mg/l (M17). The relative high concentration of boron, 0.4 l (M13) and 1.6 mg/l (M17), suggests a deep circulation of these waters through the crust.

Other springs present the Na-HCO_3 geochemical character with low contents of Cl and B. They have high concentration of Ca and Mg, which suggests the waters of meteoric origin of shallow circulation through volcanic rocks. Due to the solubility of calcite and chlorite which increases as temperature falls, and high concentrations of Ca and Mg in these springs, it is evident that in these cases the water-rock interaction occurred at low temperatures.

5. GEOTHERMOMETRY AND WATER-ROCK EQUILIBRIUM STATE

The state of equilibrium and temperatures of water-rock interaction are shown in a Na-K-Mg ternary diagram (Fig. 4). Well discharges are close to the full equilibrium line at temperatures between 270°C and 290°C. Their position is slightly beyond the theoretical line.

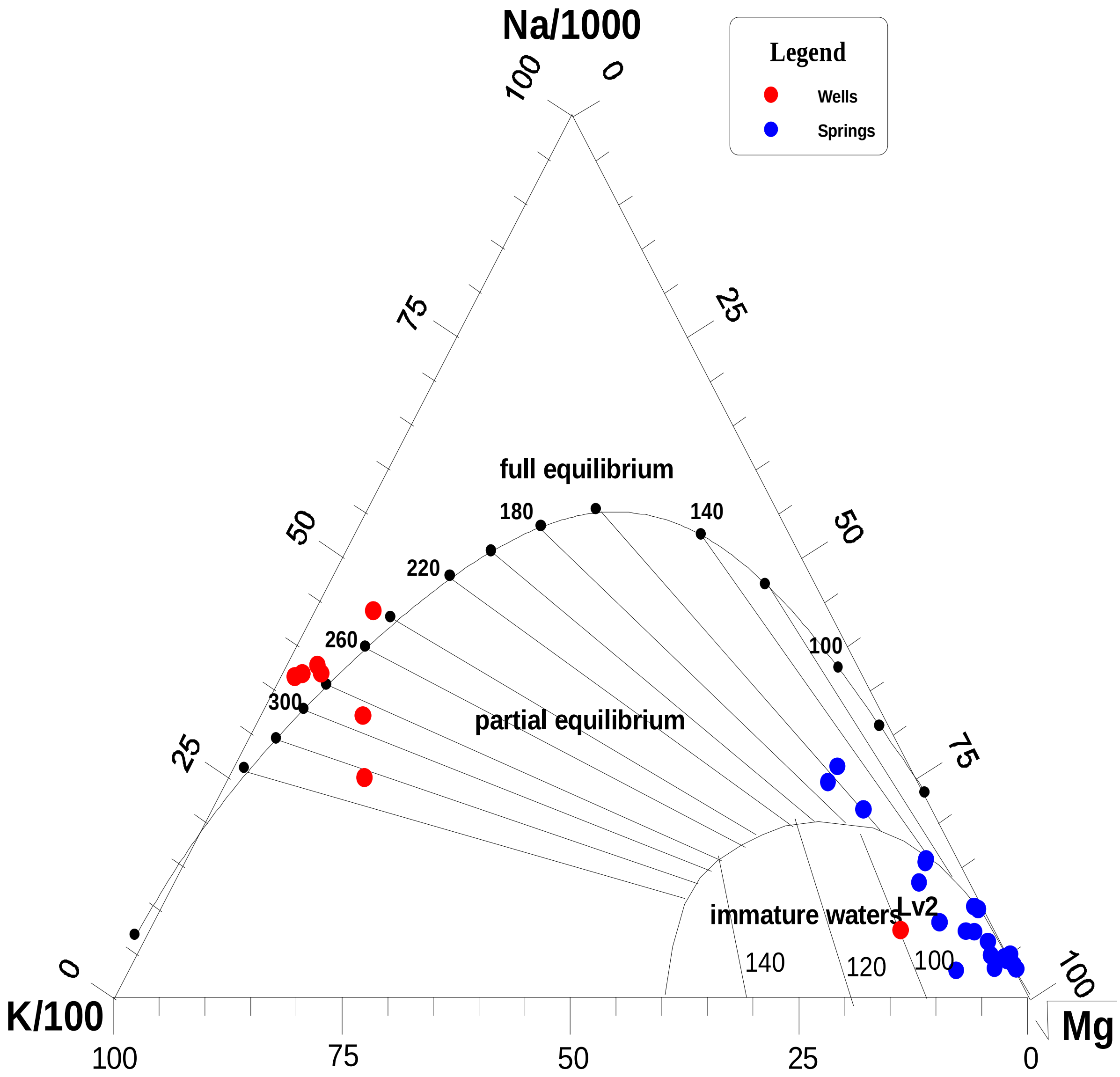

Figure 4: Evaluation of Na-K-Mg temperatures for springs, domestic wells and geothermal wells

Figure 4 is also utilized for determination of the equilibrium state and temperatures at which water-rock equilibrium of the hot springs took place during the rise towards the surface. The samples originated from El Mezquite (M17), El Tule (M13) and Alamo (M16) are located in the region of partial equilibrium. The Na/K geothermometer indicates temperatures that go from 160 (M13) to 180°C (M17).

The Na-HCO3 springs are located towards the corner of Mg and present a temperature of the K/Mg geothermometer, less than 100°C (Fig. 4). This confirms that they are shallow waters that have equilibrated with the rock at low temperatures. Now, the hot springs located in the field, which are acid-sulfate, also fall in the region of shallow waters. Also we can say that there is no interaction between the deep reservoir water and shallow groundwater. Verma (2003) presented the limitations in the application of cation-exchange geothermometers. His work suggests that the cation exchange geothermometers are violating the basic laws of thermodynamics.

6. CHEMICAL COMPOSITION OF REVERVOIR WATERS: EXCESS OF STEAM

An excess of steam is considered when the total discharge enthalpy of a well exceeds saturated liquid at the reservoir temperature. The discharge enthalpy of wells at the Las Tres Vírgenes geothermal field varies from 828 to 1391 kJ/kg. The enthalpy values are lower than that of saturated liquid at the corresponding reservoir temperatures. It means that there is only liquid phase in the reservoir.

The total discharge conditions of chemical compositions of the production well waters were corrected to the reservoir conditions (Arnorsson et al. 1983). The concentrations of solutes in the total discharge are very similar to those of the reservoir, which also indicate that the wells produce from a liquid dominant zone (Table 4).

7. GAS CHEMISTRY AND THERMOMETRY

The chemical compositions of gases can be used to estimate deep temperature and their origin. The composition of well gases at the Las Tres Vírgenes geothermal field is very similar to what is expected in a geothermal environment. CO_2 is predominant gas >95% in dry base by weight, and

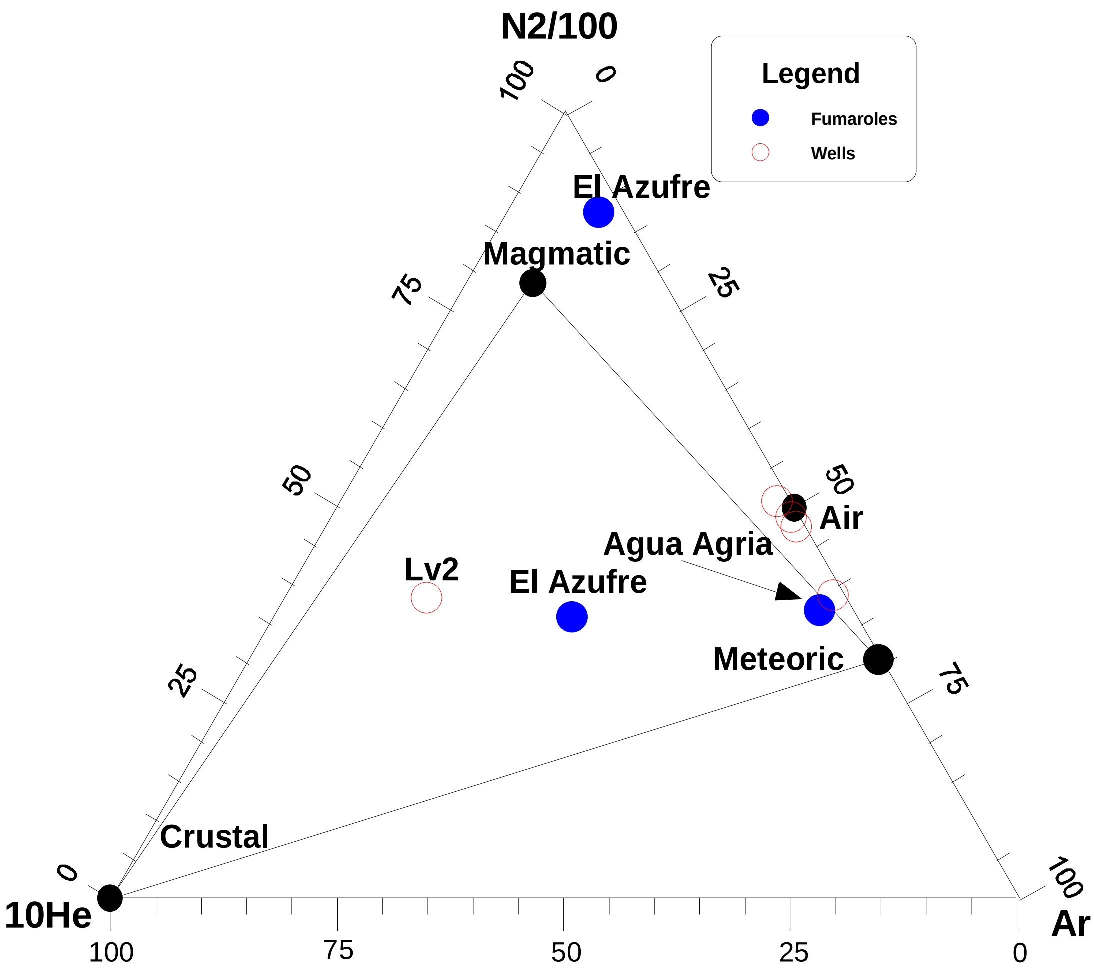

Figure 5: Relative molar contents of N_2, He and Ar of waters in the Las Tres Vírgenes geothermal field

H_2S varies from 1.1 to3.27% (Table 3). Temperatures calculated by gas geothermometer (Giggenbach 1991) vary from 254 (LV-5) to 289°C (Lv-3). These temperatures are consistent with measured temperatures and these calculated from the Na/K and SiO_2 geothermometers.

The most readily accessible group in thermal gas discharges consists of N_2, Ar and He. Ar and He. These are noble gases that are chemically inert. N_2 may take part in chemical reactions to form NH_3 (Giggenbach 1988). However, N_2 is the predominant nitrogen species in thermal gases. Giggenbach (1988) developed a triangular diagram (Fig. 5) on the basis of a large number of analyses of N_2, He and Ar contents were discharged from a wide variety of terrestrial sources. This triangular diagram was found to occupy a space delineated by three major source components: A meteoric component, represented by air saturated groundwater, and contributing N_2 and Ar in the molar ratio of 38, a magmatic component characterized by increased N_2/Ar ratios of around 800 (these ratios of up to 2,000 have been observed in the crust components made up largely of radiogenic He (Giggenbach 1988)).

The wells Lv-1, Lv-3, Lv-4, Lv-5 and Lv-8 are located on the mixing line of the magmatic origin gases and air saturated shallow water (Fig. 5). The Lv-2 well is located on the mixing line of gases, originated by the deep circulation of water and gases of atmospheric origin (air). The high content of He was detected in this well and in the fumarole El Azufre. Tello (1996) suggested a slow circulation of magmatic fluids in the crust. Quijano (1984) reported the magmatic origin of El Azufre. Tello (1996) found that the fumarole El Azufre presented the signature of deep circulation fluids. We found that the content of magmatic gases in this sample is less.

Figure 6 shows a plot of log H_2/Ar versus log CO_2/Ar. A full equilibrium line is defined for the equilibration of all gases dissolved in a single liquid phase. The horizontal line corresponds to compositions expected for equilibrium in the vapor phase. The tie lines describe intermediate conditions (Giggenbach, 1980). The gases from Lv-1, Lv-3 and Lv-4 fall close to the theoretical liquid phase, full equilibrium line at a temperature of 280°C.

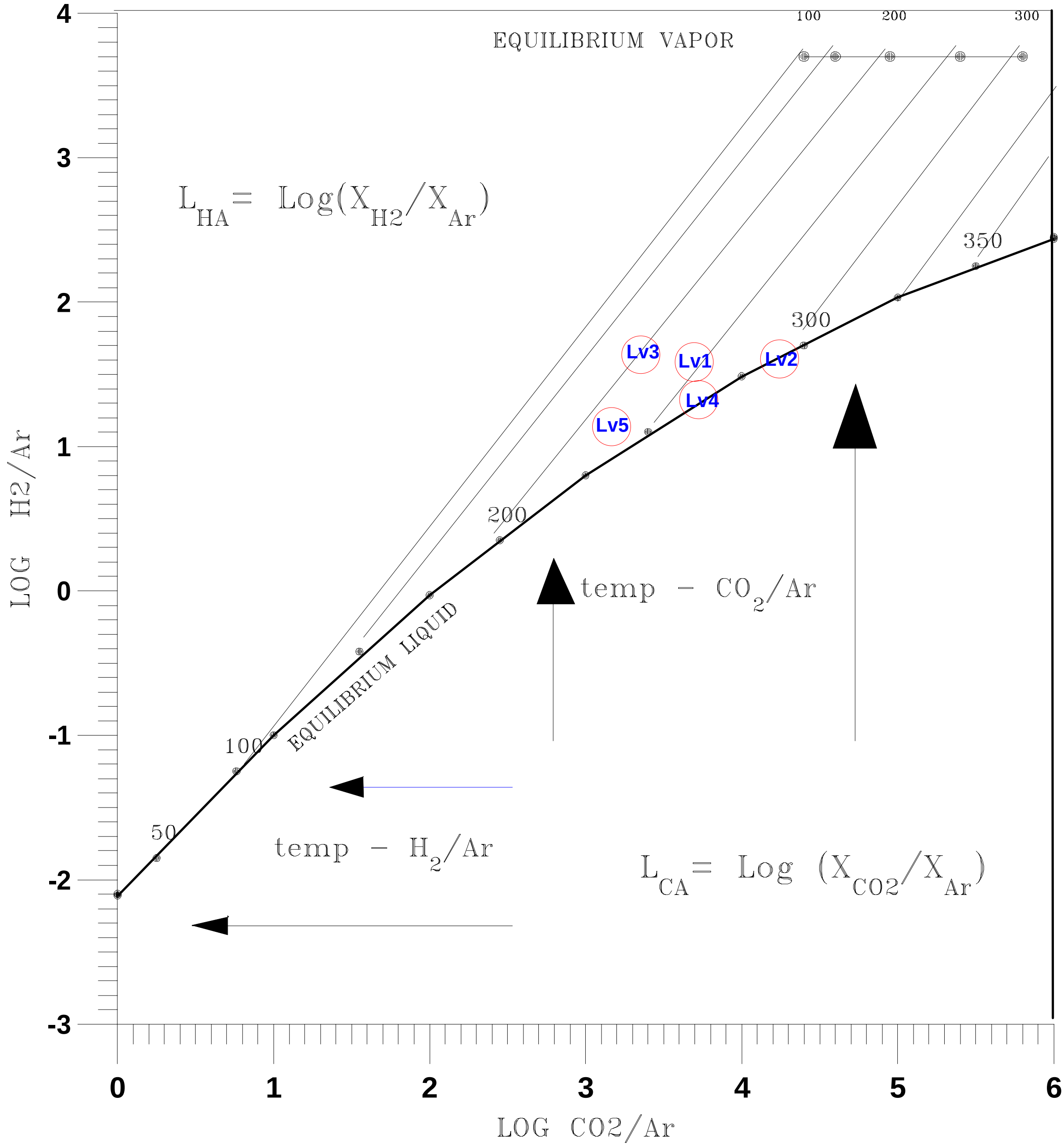

Figure 6: Evaluation of H_2/Ar, CO_2/Ar deep conditions in the Las Tres Vírgenes geothermal field.

8. ISOTOPIC CHARACTERISTICS

Figure 7 shows a relation between δ^{18}O and δD for the waters from the Las Tres Vírgenes geothermal field. The isotopic data were corrected to the total discharge. The wells present a δ^{18}O shift which is a characteristics of geothermal origin fluids. This enrichment of δ^{18}O is due to the water-rock interaction at high temperatures. On the contrary, most of the hot springs are located on the line of meteoric waters. Their isotopic data were used to calculate the local meteoric water line (LML). The fit of the data by the least-squared method provided a slope with a value of 7.52 and a correlation coefficient of 0.95. The equation of the line was found to be $\delta D = 7.52\delta^{18}O + 5.57$ (Portugal et al. 2000). The samples used in the regression were from Regis, Mezquital, Bonfil, Sn. Ignacio, R. Vírgenes, Cueva and Reforma. The isotopic compositions from Santa Lucia, A. Caliente and El Azufre springs are the characteristics of waters, modified by evaporation at atmospheric temperature (Table 5).

The values of the Local Meteoric Line (LML) equation as well as isotopic data from thermal springs and geothermal water (wells Lv-1, Lv-4, Lv-5) were used to estimate the isotopic composition and elevation level of the fluids which recharge the geothermal reservoir. According to Fontes (1980), the intersection point between the local meteoric line and the interpreted regression line of the geothermal fluids represent the isotopic composition of the initial meteoric water recharging the geothermal reservoir. As a result, values of δ^{18}O = -9.7 ‰ and δD = – 67.3 ‰ were derived for the recharge in Las Tres Vírgenes.

The isotopic data from the geothermal wells do not show a relationship with seawater. Also the deuterium concentration in the geothermal water is slightly higher than concentrations measured in the shallow aquifers and surface outflows of the study area (Portugal et al. 2000).

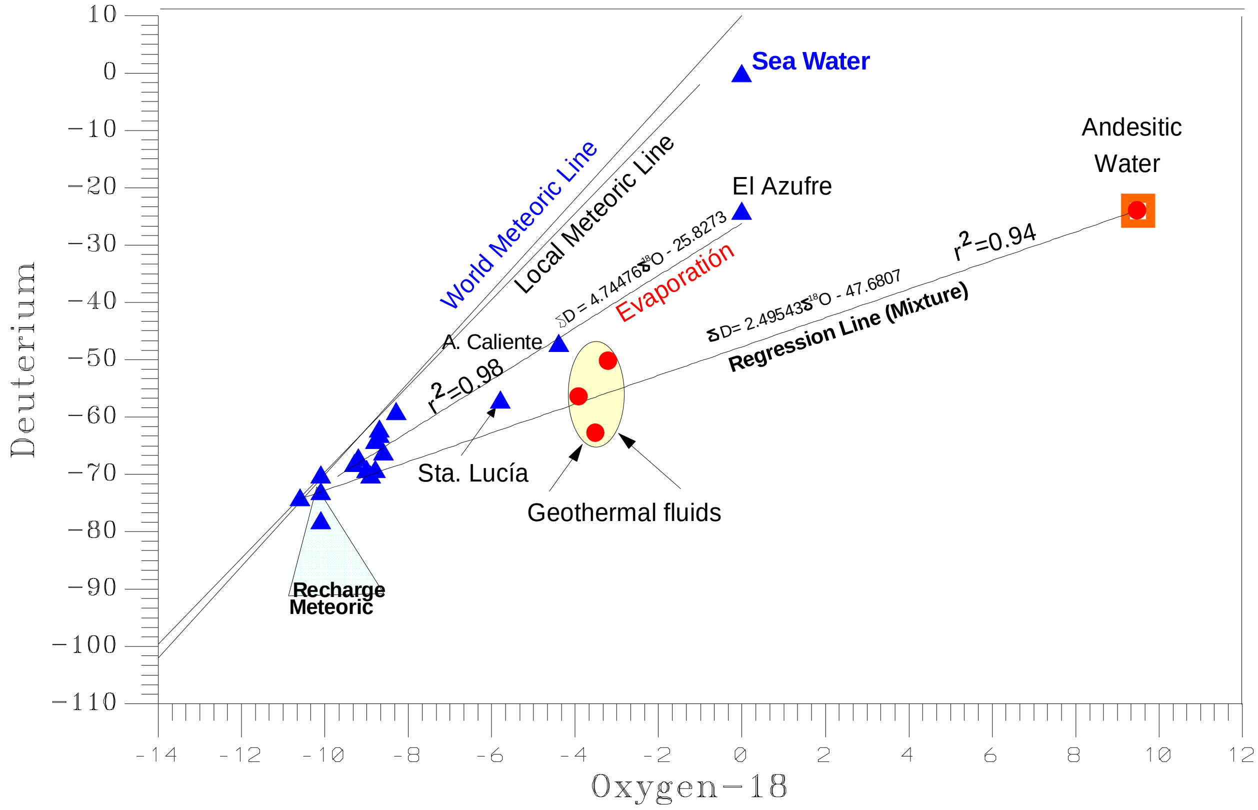

Figure 7: δ^{18}O vr. δD relation in the Las Tres Virgenes geothermal field.

9. CONCLUSIONS

The water produced by the wells of the Las Tres Vírgenes geothermal field is sodium-chloride type, a characteristics of geothermal brine. The corrected chemical compositions in the total discharge and the reservoir indicate that the reservoir is located in the liquid dominant zone.

The chemical composition of gases from the wells is similar to what is expected in a geothermal environment. CO_2 is predominant gas >95% in dry base weight, and H_2S varies from 1.1 to 3.27 %. Temperatures calculated by means of the gas geothermometer vary from 254°C (LV-5) to 289°C (Lv-3). These temperatures are consistent with measured temperatures and the calculated ones by the means of the Na/K and SiO_2 geothermometers.

It can also be concluded that the reservoir is in equilibrium. The gases of magmatic origin have been totally neutralized by the rock. The temperature of the water-rock and gas-liquid equilibria is in the range 254 to 290°C.

The Isotopic composition of the wells presents an enrichment in δ^{18}O, a product of the water-rock interaction at high temperatures. However, the hot springs are located, in general, on the meteoric water line. The isotopic composition from Santa Lucia, A. Caliente and El Azufre springs is modified by evaporation at atmospheric temperature.

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Table 1. Chemical composition of the springs and domestic well.

No	Place	C.E. µmhos/cm	PH	Ts °C	Na Mg/l	K	Ca	Mg	HCO_3	Cl	SO_4	SIO_2	B	Li	A.T. meq/l
1	El Azufre	6000	2.1	97	19.4	6.8	30	5.0	0.0	6.0	2444	384	3.2	0.00	N.D.
2	A. Caliente	2180	8.4	53	290	16.4	68	26.0	333	17.0	454	118	0.6	0.10	6.36
3	Agua Agria	1980	2.9	97	12	14.0	30	3.2	0	13.6	850	280	0.1	0.00	N.D.
4	El Yaqui	1990	7.9	26	270	4.0	30	9.5	350	100	340	85	0.4	0.10	6.24
5	SanAlberto	3220	7.6	24	278	15.0	240	156	344	100	1439	161	0.8	0.20	6.20
6	San Regis	721	8.0	24	56	5.9	54	4.8	230	76.8	23.0	81.6	0.0	<0.01	4.13
7	El Mezquital	603	7.8	23	81.5	4.9	36	18.8	273	42.3	14.8	59	0.2	<0.01	4.80
8	La Cueva	604	7.8	24	46	3.6	54	35.6	283	42.3	11.6	79	0.7	<0.01	5.00
9	La Cuevita	708	7.8	24	67	3.4	54	28.6	253	92.2	21.2	83	1.3	<0.01	4.60
10	El Carrizo	3420	8.0	31	513	9.3	224	31.6	249	192	1477	94	1.4	0.22	4.60
11	El Palmito	834	7.9	23	120	1.6	38	21.4	224	119	28.5	60	0.2	<0.01	4.00
12	La Palma	2150	7.8	31	234	22.9	187	10.4	287	131	734	125	1.2	0.16	5.10
13	El Tule	1993	7.9	24	202	10.4	103	88.6	361	405	81.6	62	0.4	0.04	6.30
14	Santa Ana	3290	8.1	24	459	24.9	159	11.6	256	507	757	91	1.1	0.17	4.60
15	Golfo de Cali.	51400	8.1	22	11000	350	417	860	131	18380	2987	5.0	4.7	0.16	2.61
16	El Alamo	1040	8.7	30	216	6.0	21	1.6	309	137	57.9	89	0.5	<0.01	6.10
17	El Mezquite	2780	9.0	30	606	18.4	160	13.4	200	453	199	99	1.9	0.17	13.30
18	La Reforma	4220	7.9	24	768	29.9	145	7.8	462	642	816	103	1.0	0.19	8.00
19	Palmita II	2500	7.7	18	393	16.9	158	1.3	340	311	584	105	0.5	0.11	5.90
20	San Ignacio	955	7.9	24	98	5.0	67	5.2	358	115	22.4	90	0.8	0.03	6.20
21	Santa Lucía	955	8.7	26	140	10.2	41	5.8	335	111	31.5	64	0.6	0.01	6.50

Table 2. Chemical composition of geothermal wells.

Well No	Date Dd/mm/yy	Pc kg/cm^2	Enthalpy kJ/kg	C.E. µmhos/cm	pH	Na mg/l.	K	Ca	Mg	HCO_3	Cl	SO_4	SIO_2	STD
Lv-1	27/01/96	5.25	930	24820	7.6	4525	736	241	0.36	97	8051	77	395	14338
Lv-2	25/01/88	-	-	513	7.5	46	9	56	0.50	140	49	15	25	347
Lv-3	3/05/96	6.24	1298	22100	7.5	4110	693	92	0.10	96	7335	69	560	13073
Lv-4	26/05/97	7.51	1391	26900	7.2	5333	923	197	0.10	68	9601	42	740	17120
Lv-5	21/03/97	2.57	828	22800	7.3	4917	778	319	0.27	114	8554	99	162	15156
Lv-8	10/10/98	2.5	1156	16300	8.0	3344	378	303	0.27	1	5360	52	582	10071

Table 3. Chemical composition of gases from Las Tres Vírgenes geothermal field. The concentrations are given in mmol/mol.

Name	Cg	CO_2	H_2S	NH_3	He	H_2	Ar	N_2	CH_4
El Azufre *	-	967	9.05	0.30	-	20.0	0.003	1.75	1.73
A. Agria *	-	867	30.6	2.34	-	96.0	0.052	3.14	-
El Azufre**	-	930	47.7	0.01	0.012	5.09	0.128	13.61	1.45
Lv-1	0.49	950	25.6	4.15	0.0	7.28	0.19	12.0	0.49
Lv-2	1.81	966	15.51	12.98	0.075	2.15	0.054	2.32	0.54
Lv-3	1.15	938	11.95	2.6	0.0	17.52	0.41	37.55	1.20
Lv-4	1.92	969	2.25	8.74	0.0	3.80	0.18	19.04	1.16
Lv-5	1.48	924	3.27	0.57	0.0	8.5	0.63	60.64	2.7

*data from Quijano (1984), **data from Tello (1996)

Cg is the total gas in % weight (dry basis)

Table 4. Water reservoir chemical compositions at reservoir and total discharge conditions in mg/l.

WELL No	DATE dd/mm/aa	ENTHALPY kJ/kg	Na	K	Ca	Mg	SiO_2	Cl	B	T(°C) Na/K
					Concentration in the total discharge					
Lv-1	27/01/96		3475	565	185	0.28	303	6183	146	263
Lv-3	30/05/96	1298	2602	426	108	0.12	368	4759	108	263
Lv-4	26/05/97	1391	3104	537	115	0.06	431	5588	108	269
Lv-5	21/03/97	828	3929	644	259	0.22	260	6734	178	263
					Concentration at the reservoir conditions					
Lv-1	27/01/96	930	3475	565	185	0.28	303	6183	146	263
Lv-3	30/05/96	1298	2863	469	118	0.13	405	5235	119	263
Lv-4	26/05/97	1391	3484	603	129	0.07	484	6273	121	269
Lv-5	21/03/97	828	3929	644	259	0.22	260	6734	178	263

Table 5. Chemical and isotopic composition of the springs and domestic wells used in this study.

No	PLACE	DATE	Ts °C	C.E μmhos/cm	PH	Cl mg/l	$\delta^{18}O$ SMOW	δD SMOW
1	El Azufre	13/06/97	98	5020	1.4	13.0	0.0	-24
2	A. Caliente	13/06/97	44	1877	8.2	24.0	-4.4	-47
3	Agua Agria	13/06/97	-	-	-	-	-	-
4	El Yaqui	13/06/97	32	1384	7.7	144.0	-8.7	-62
5	SanAlberto	14/06/97	34	2320	7.7	200.0	-8.9	-70
6	San Regis	12/06/97	28	752	7.2	88.0	-9.3	-68
7	El Mezquital	12/06/97	31	626	7.3	46.0	-10.1	-73
8	La Cueva	12/06/97	30	623	6.9	42.0	-8.7	-63
9	La Cuevita	-	-	-	-	-	-	-
10	El Carrizo	-	-	-	-	-	-	-
11	El Palmito	13/06/97	29	868	7.4	119.0	-8.8	-64
12	La Palma	11/06/97	29	2260	7.2	131.0	-9.0	-69
13	El Tule	-	-	-	-	-	-	-
14	Santa Ana	14/06/97	27	2930	7.0	400.0	-9.2	-67
15	Golfo de Cali.	14/06/97	22	51400	8.1	18,380	0.0	0.0
16	El Alamo	10/06/97	34	1064	8.4	137.0	-10.1	-70
17	El Mezquite	10/06/97	32	2730	8.2	192.0	-8.6	-66
18	La Reforma	10/06/97	29	4040	7.2	642.0	-10.6	-74
19	Palmita II	11/06/97	26	1470	7.0	131.0	-9.2	-67
20	San Ignacio	12/06/97	31	1179	7.4	146.9	-8.8	-69
21	Santa Lucía	12/06/97	30	949	8.3	99.6	-5.8	-57
22	R. Las Vírgenes	12/06/97	32	1378	7.5	228.2	-10.1	-78
23	Rancho Bonfil	12/06/97	31	1049	7.2	91.8	-8.3	-59