

ORIGIN OF ACIDITY IN THE LOS HUMEROS, MÉXICO, GEOTHERMAL RESERVOIR

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ABSTRACT

Chemical and isotopic analysis of geothermal fluids were carried out at the Los Humeros, México, geothermal field in order to establish the water-rock equilibrium state and to know the origin of acidity in the reservoir. According to the water-rock equilibrium state, the Los Humeros geothermal reservoir is in an unbalanced state. This is probably due to recent volcanism, which indicates that the magmatic components in the geothermal fluids are not neutralized by reaction with feldspar and mica.

The superheated steam contains HCl, which condenses or mixes with liquid at moderate temperature ($< 300^{\circ}\text{C}$). This is in agreement with the Los Humeros case, because high concentrations of HCl were detected in the steam phase. In addition, high concentrations of boron and arsenic also favor the definition of the Los Humeros as a recent volcanic system. Most wells of this field have high fluid enthalpy and almost all produce high quality steam at the wellheads. Chemical characteristics of the fluids show that the produced brine is low-saline water, whose geochemical character varies according to both well type and production. Shallower wells produce sodium bicarbonate (H-1) type water, whereas deeper wells exhibit a sodium chloride geochemical type (H-6). It was also found, according to vapor excess data, that well H-1 is located in a zone where the liquid phase is dominant, while the remaining wells are producing in a two-phase zone. As a result, the chemical composition of the total discharge from well H-1 is the same in the reservoir.

Measured temperatures at bottomhole vary (between 260 and 340°C) and are in agreement with geothermometer calculations (Na/K of $295 \pm 10^{\circ}\text{C}$), (H_2/Ar of 270 to 340°C). The isotopic composition of the Los Humeros wells shows an $\delta^{18}\text{O}$ shift which is characteristic of fluids of geothermal origin that have reached equilibrium with the rock at high temperatures. The springs in the area are mostly located on the meteoric line. The Alchichica sample has an isotopic composition of evaporated water.

1. INTRODUCTION

This paper was supported by an IAEA-Coordinated Research Programme (IAEA-CRP) on the use of isotope techniques for the investigation of acidic fluids in geothermal reservoirs in exploitation (1997-1999). The Los Humeros field is the second geothermal reservoir after Los Azufres to produce electricity in the area of the Mexican Volcanic Belt (MVB). The Los Humeros geothermal field is situated in the eastern part of the MVB, at an average altitude of 2800 masl about 200 km east of México city (Figure 1). Exploration work in the area including detailed geological, geophysical and geochemical studies began

at the end of the 1960s. The exploration activities cover an extension of about 80 km². The first production well was drilled in 1980 and in 1990 the first over-wellhead power plant was constructed. At present there are 7 power plants of 5 MWe each. The Los Humeros geothermal system has an installed capacity of 35 MWe and approximately 40 wells have been drilled. CFE is planning in the near future the expansion of the field, with the installation of two more units of 25 MWe each. Two reservoirs have been identified in this field although the deeper one has a very high temperature ($>350^{\circ}\text{C}$), its exploitation could not be feasible due to the high content of HCl. Acidic fluids have been found in many geothermal reservoirs and their corrosiveness in geothermal plants requires an understanding of the origin of acidic fluids in the reservoir (Verma et al., 1997).

The objective of this paper is to integrate all available isotopic and chemical data on the Los Humeros geothermal field, in order to determine the water-rock interaction state and to define the origin of the acidity of the fluids produced by the wells.

2. GEOLOGIC SETTING

The Los Humeros geothermal system is located on a complex volcanic Caldera system (less than 500,000 years old), which is at the eastern end of the Plio-Pleistocene Trans-Mexican Volcanic Belt (Yañez, 1980; Ferriz, 1982; Ferriz and Mahood, 1984; Martínez, 1983; Negedank et al., 1985). Thermal manifestations as well as most of the exploration bore-holes are located in a small area of 35 km² called the Central Collapse (Figure 1). Geology studies of both cutting and surface samples show that the basement of the region is formed by Late Cretaceous limestone sequences (Viniegra, 1965; Yañez, 1980). Most bore-holes penetrate a hydrothermally altered rock sequence of more than 2200 m thick consisting of andesites, dacites, rhyodacites, rhyolitic tuffs, rhyolites and some basaltic rocks overlying a complex basement of more than 500,000 years old (Ferriz and Mahood, 1984; Martínez, 1993). The most recent event was an eruption of an olivine basalt lava flow that occurred less than 20,000 years ago.

The subsurface structure at the Los Humeros system has been inferred from geophysical studies (Campos and Arredondo, 1992). It consists of a sequence of blocks surrounded by fractures and faults arranged as grabens and horsts and associated with the process of collapse Caldera formation (Martínez, 1996).

Petrographic and geochemical studies were carried out at the Los Humeros system by Viggiano and Robles (1988); Prol (1990); Martínez (1993); Martínez and Alibert (1994). These studies showed that volcanic rock sequences were affected by the circulation of hot water ($>290^{\circ}\text{C}$), with less than 2500 mg/l of total dissolved salts, transforming the primary rock forming minerals into stable phases at new physico-chemical

conditions. Geochemical analysis of the present-day fluids discharged from the bore-holes of the geothermal system suggest that these fluids are the result of mixing between geothermal fluids and meteoric water, plus the addition of a high percentage of steam (between 30 and 80%) at shallow depth (Tello, 1992; Barragán et al., 1991; Martínez, 1993). Presently, the geothermal system behaves as a mixed system with two fluid phases and high enthalpy.

Hydrothermal alteration found in cores and cutting samples consists of a shallow argillic zone (0-600 m) with mostly zeolites, calcite and oxides, whereas at intermediate zones (600 – 1700 m), the alteration style is propylitic (epidote, Chlorite, calcite, quartz and sulfides). Calc-silicate alteration containing amphibole, garnet, clinopyroxene and biotite is found in deep zones of the system (>1700 m) where temperatures are over 320°C. Pyrite is the most ubiquitous sulfide mineral throughout the altered volcanic sequences.

3. GEOCHEMISTRY OF GEOTHERMAL BRINE AND SPRINGS

The CFE systematically performs chemical analysis of fluid coming from production wells (López, 1982; López and Munguía, 1989; Barragán et al., 1991; Truesdell, 1991; Tello, 1992, 1994; Tovar, 1999). The chemical analysis of water and gases of samples from 1981 to 1999 display significant variations in the concentrations of main ions. Chloride concentration range from 1.4 to 982 ppm. The most important contribution to the total dissolved solids comes from boron (from 67 to 3169 mg/l), Table 1.

In order to determine the type of fluid produced by the wells and springs, figure 2 was prepared. This figure illustrates the contents of Cl, HCO₃ and SO₄ (Giggenbach, 1989). As seen, only deep wells discharge a mixture of chloride and bicarbonate waters from a zone where deep geothermal fluid, steam heated waters and cold meteoric waters are mixed (Tello, 1992). Enthalpy data show that the deep production zone (deeper than 1500 m) in most wells of this geothermal field seems to be located in to a two phase reservoir (Tello, 1992).

CFE has also monitored the water composition of 41 springs on the boundaries of the Los Humeros, in order to determine the relationship among them (Table 2). This helps to obtain environmental knowledge of the shallow aquifer, and to determine if the shallow aquifer has been modified by both the exploitation and the injection of fluid into the reservoir. The springs display sodium-bicarbonate geochemical character with low contents of chlorides (<12 mg/l and of boron (<1 mg/l), and high concentration of calcium suggesting that meteoric fluids are circulating through shallow volcanic rocks and that water-rock interaction occurred at low temperatures because the solubility of calcite increases as temperature decreases.

4. GEOTHERMOMETRY AND SOLUTE-ROCK CHEMICAL EQUILIBRIUM

Figure 3 shows the state of equilibrium and the water-rock interaction temperatures. This diagram is useful for evaluating the Na-K-Mg-geothermometers (Giggenbach, 1988). Only well H-37 is close to the full equilibrium line. Its deep

temperature lies a little bit beyond the theoretical line due to steam loss because these samples were collected at atmospheric pressure (H-29). However the rest of the wells fall in the partial equilibrium area, although wells H10, H15, H17, H32 and H35 fall in the area of shallow waters. These wells produce scarce water, making it very difficult to take the sample. The water-rock equilibrium temperature of the wells ranges between 200°C and 300°C. Figure 3 is also used to determine the equilibrium state and the water-rock equilibrium temperatures of the springs as they rise towards the surface. One can observe that only two samples are located in the region of partial equilibrium. The rest of the sodium-bicarbonate springs are displaced towards the magnesium field and they display a temperature of the K/Mg geothermometer less than 100°C. This confirms that they are shallow waters that have equilibrated with the rock at low temperatures.

5. GAS CHEMICAL EQUILIBRIUM AND THERMOMETRY

The chemical composition of the gases can be also used either to estimate deep temperatures and/to establish their origins. The composition of well gases at the Los Humeros is typical of a geothermal environment. CO₂ is the predominant gas (about 95% in dry base volume), and the H₂S varies from 1.0% to 12.3% molar concentrations (Table 3). Temperatures calculated by means of the H₂/Ar gas geothermometer of Giggenbach (1989); vary from 270°C (H3) to 338°C(H12) (Figure 4). These temperatures are in some cases consistent with both measured and calculated temperatures obtained using K/Na (Giggenbach, 1989) geothermometers.

In Figure 5 values of log H₂/Ar versus log CO₂/Ar were plotted. This figure shows a full equilibrium line defined for equilibration of all dissolved gases in a single liquid phase. In the same figure the horizontal line corresponds to compositions expected for equilibration in the vapor phase. The lines describe intermediate conditions, the addition of equilibrium vapor or the loss of Ar prior to re-equilibration (Giggenbach, 1989). Most well discharge falls near the theoretical liquid phase line, which is the full equilibrium line. The position of well H-12 and the U-3 samples indicate either the admixture of equilibrium vapour or the loss of Ar.

N₂, Ar and He form the most readily accessible group in thermal gas discharges. Ar and He are noble gases and chemically inert. N₂ may take part in chemical reactions to form NH₃ (Giggenbach, 1989). Generally, N₂ is the predominant nitrogen species in thermal gases. Giggenbach (1988) provided a triangular diagram on the basis of a large number of analysis of gases discharged from a wide variety of terrestrial sources. Figure 6 shows data points of relative N₂, He and Ar contents. This triangular diagram is delineated by three major source components: a meteoric component, represented by air saturated groundwater and contributing N₂ and Ar with a molar ratio of 38, a magmatic component characterized by N₂/Ar ratios around 800, and a crustal component made up largely of radiogenic He. Helium-4 content is expected to increase with increasing gas-residence time in the crust (Giggenbach, 1989).

Relative N₂:He:Ar contents are shown in figure 6 which shows that the gases of wells H3, H6, H9, H12, H20 and H30

are located on a mixture line between gases of magmatic origin and air saturated shallow water. The H15 is located in the zone of waters recently saturated with air. The low content of He detected in the rest of the wells suggests very low circulation of magmatic fluids in the crust (Figure 6). A very well defined linear distribution exists between gases of very deep circulation and gases of atmospheric origin (air). Analysis of gases from well H1 indicates a larger residence time of fluid in the crust. This is logical since H-1 is the shallowest well in the field.

6. ISOTOPIC GEOCHEMISTRY

Verma (et al, 1997) conducted a monitoring of the chemical and isotopic composition of rainwater at Los Humeros and its surrounding, in order to determine the rain water quality in the region. A side product of that study was the local meteoric line. The isotopic data had a wide spread. The effects of altitude and precipitated volume are prominent. However, the data have a very good linear correlation between δD and $\delta^{18}O$ values and the equation for this line (local meteoric water line) is $\delta D = 7.75\delta^{18}O + 12.14$. The volume-weighted-average isotopic composition of rainwater is -11.00 for $\delta^{18}O$ and -78.00 for δD .

The isotopic compositions ($\delta^{18}O$ and δD) of surface manifestations (springs and hydrological well) are taken from Tello (1992). Figure 7 shows the isotopic composition of all types of water in the region including local and worldwide meteoric water lines. The averaged isotopic composition of geothermal wells (production and reinjection) are also plotted in figure 7. The deep reservoir composition is calculated using the conservation enthalpy approach. The wellhead enthalpy depends on the wellhead opening. Thus it would be more accurate to calculate the deep reservoir composition with the of WMO-IAEA data for the worldwide sampling stations.

There is a wide spread in the total discharge composition of production wells. It could be associated to the deep mixture of geothermal reservoir fluids. Although the rainwater data are only for one year, the variation with altitude, precipitated volume, and annual temperature are quite consistent as observed in the isotopic data of WMO-IAEA data for the worldwide sampling stations. The geothermal wells present a $\delta^{18}O$ shift characteristic of fluid of geothermal origin. This enrichment of $\delta^{18}O$ is due to water rock interaction at high temperatures. In contrast, most of the springs are located on the meteoric water line. For the samples of the lagoons and wheels such as Alchichica and Artesiano their isotopic composition is characteristic of waters modified by evaporation processes at atmospheric temperature.

The isotopic data of a hydrological well within the caldera are -11.89 and -85.0 for $\delta^{18}O$ and δD , respectively. These are slightly lighter than the averaged rainwater data. The isotopic data of geothermal wells are heavier in both oxygen and deuterium. This could be an effect due to evaporation.

7. EXCESS STEAM

There exist an excess of steam if the discharge enthalpy of a well exceeds that of saturated liquid at the temperature of the reservoir (Arnorsson, 1982). The discharge enthalpy of wells at Los Humeros varies from 1179 to 2726 kJ/kg. High

enthalpy discharge reflects two phases (steam and water) in the reservoir. Only well H-1 is producing in a liquid-dominated zone. The rest of wells are located in two-phase zones (Tello, 1992).

8. ORIGIN OF ACIDITY

Truesdell (1991) explained the occurrence of acid fluid in geothermal reservoirs. It could be produced by either the introduction of volcanic fluids or from volatilization and transport of HCl. It is expected to appear in the boiling high temperature reservoirs as they lose liquid and start producing superheated steam. The occurrence of superheated, high HCl steam is produced by the flow of fluids from a deep dry reservoir to a shallow water-saturated reservoir. Strong corrosion and scaling results from fluid mixing and reacting with casing and rock (Verma, 1997).

There are several hypothesis about the origin of acidity in Los Humeros:

- 1) According to water-rock chemical equilibrium the Los Humeros geothermal reservoir is in an unbalanced state (Tello, 1992). Its occurrence in geothermal systems associated with recent volcanism like Los Humeros probably indicates that the reservoir fluids were derived from volcanic fluids incompletely neutralized by reaction with feldspars and micas. Superheated steam containing HCl forms acid when it condenses or mixes with liquid at moderate temperature (<300°C). That is in agreement with the Los Humeros case, because high concentrations of HCl and HF were detected in the steam phase. In addition, high concentrations of boron and arsenic indicate that the Los Humeros is a recent-volcanic system (Tello, 1995).
- 2) The Los Humeros geothermal system has been considered as being formed by two reservoirs, although there is no separation layer (lithological unit) differentiating them. The shallow reservoir contains vapor and liquid whereas the deeper one has only superheated steam and high temperature (>300°C). The production of HCl vapour in the deeper reservoir is a result of water-rock interaction at high temperature and low amount of water (Verma et al., 1997). The high corrosiveness and scaling in the wells due to these deeper fluids has limited exploitation to the shallow regions of the reservoir.
- 3) According to Truesdell (1997), the most important question regarding the Los Humeros field is the nature of the deep reservoir. The presence of acid fluids in some well discharge and evidence of subsurface acid attack of casing and country rock along with the high temperatures (300–400°C) measured downhole have been taken as evidence that a deep, acidic and hot reservoir exists at depth. The constituents that have been assumed to be from the deep reservoir include Cl, B, HCl and H₂S. However, these all are soluble in superheated steam or could result from acid attack of casing and wallrock. The “primary” constituents HCl, B and H₂S are also present in the shallow reservoir (with Cl present as NaCl). It is very important to note that in the natural state there was no evidence of acid fluids. The andesite contains calcite, feldspars, and mica; the hornfels and skarn are composed in part of carbonate rocks and normally contain calcite. If in the native state reservoir fluid contained significant HCl and B, then it would be expected that minerals such as calcite and feldspars would not occur and that boron minerals such as tourmaline would be

found. The lack of mineralogical evidence for deep acid or high boron suggests that the deep fluids observed in H-16 and H-4 may be in part artifacts of drilling formed by flows of shallow water down the wellbore (Truesdell, 1997).

A shut-in drill hole penetrating both the shallow, liquid-filled reservoir and the deep reservoir containing only high-temperature steam would be a conduit for downward flow of liquid between the two zones. Liquid flowing down the well would quickly vaporize as it reached the high-temperature zone and form highly saline brine, precipitate salts and evolve gases. Some constituents such as B (as H_3BO_3) would partition between solid and vapor. The continued downflow of upper-zone water could cause accumulation of significant quantities of alkali chlorides (mainly halite) and sulfates, boric acid, and amorphous silica and release CO_2 (from HCO_3^-) and NH_3 (from NH_4^+) into the steam. The steam in contact with this deposit of salts would have high H_3BO_3 and significant HCl formed by halite-silicate reaction. Together with well production, gases and volatile salts would be drawn upward to mix with the shallow reservoir water and produce the observed inhomogeneous fluid composition and, in some wells, acid corrosion. If this idea is correct, then shallower drilling at Los Humeros could have avoided the formation of acid steam as well as its introduction into drill holes.

CONCLUSIONS

The chemical characteristics of fluids showed that the brine produced by the wells is a low-saline water, whose geochemical character varies according to well type and production. Shallower wells produced sodium bicarbonate (H-1) type water, whereas the deeper wells exhibited a sodium chloride type (H-6). According to water-rock equilibrium state Los Humeros geothermal reservoir is in unbalanced state. According to vapor excess data, it is concluded that well H-1 is in a zone where the liquid phase is dominant, while the remaining wells are producing in a two-phase zone. Measured temperature at bottomhole varies between 260°C and 340°C. These variations are in agreement with geothermometer calculations.

There are several hypotheses about the origin of acidity in the geothermal reservoir. According to water-rock chemical equilibrium, the Los Humeros geothermal reservoir is in an unbalanced state. The magmatic components in the geothermal fluids are not neutralized by the reaction with feldspars and micas. High concentrations of HCl and HF were detected in the steam phase.

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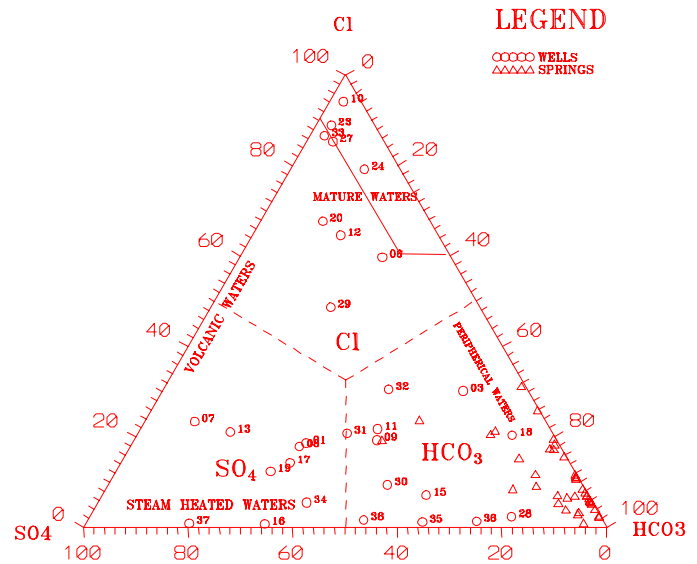


Figure 2. Relative Cl:SO₄:HCO₃ contents of geothermal brine and springs from the Los Humeros, geothermal field.

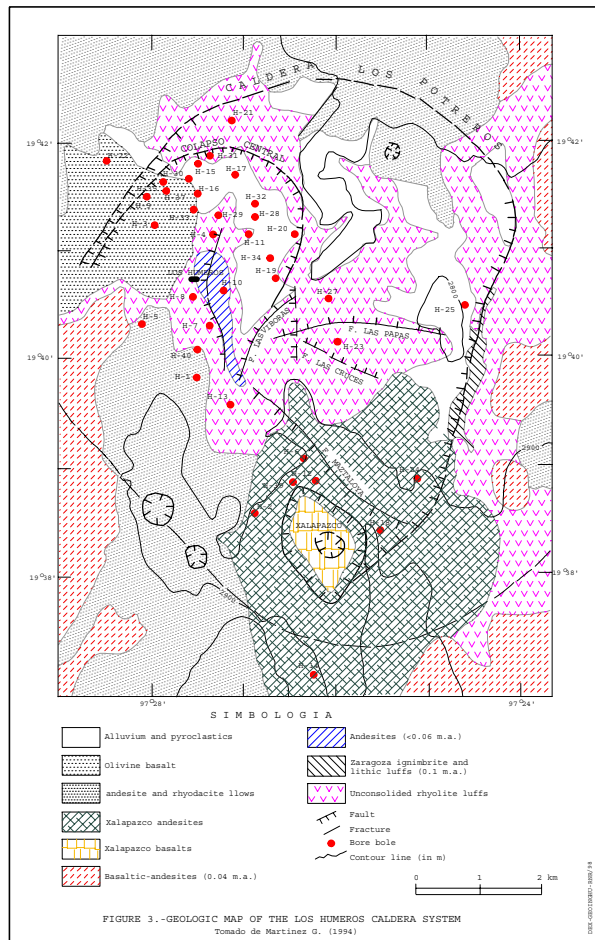


Figure 1. Geologic map of the Los Humeros Caldera system (Taken from Martínez, G., 1994).

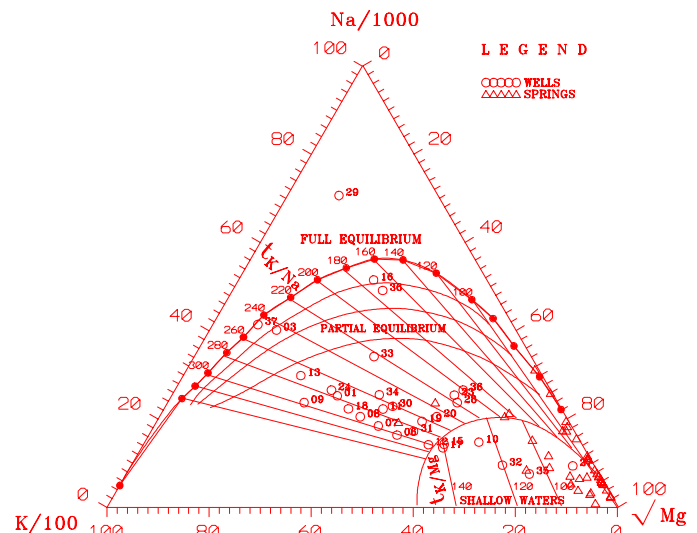


Figure 3. Evaluation of Na:K:Mg temperatures from the Los Humeros geothermal field.

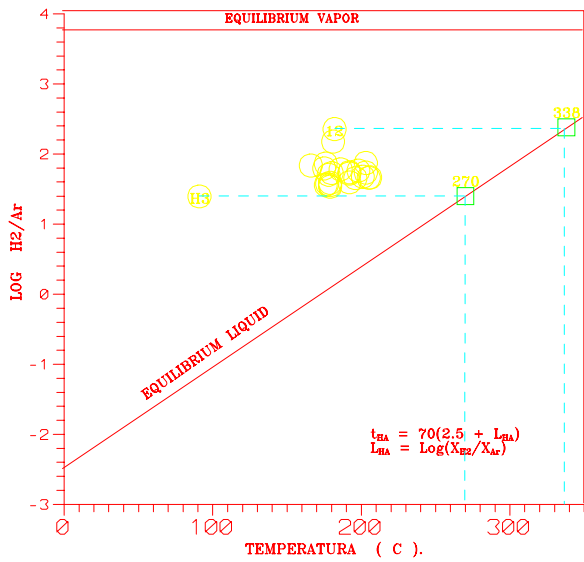


Figure 4. Estimation of H₂-Ar temperatures for gas discharges of wells from the Los Humeros geothermal field (on per mil molar basis).

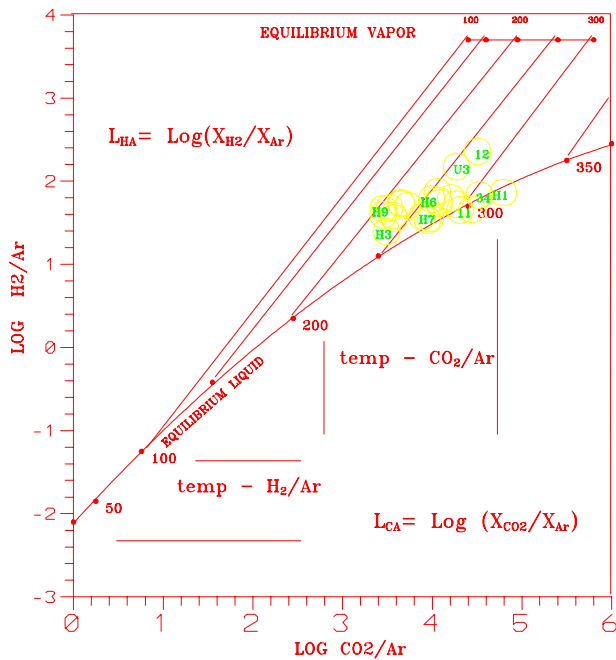


Figure 5. Evaluation of H₂-Ar, CO₂-Ar equilibration conditions for wells gas discharges from the Los Humeros geothermal field (on per mil molar basis).

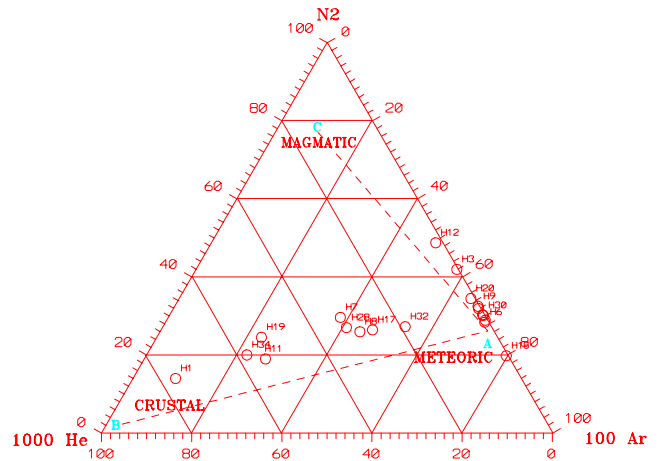


Fig. 6. Relative N₂:He and Ar contents for gas discharges of wells from the Los Humeros geothermal field (on per mil molar basis).

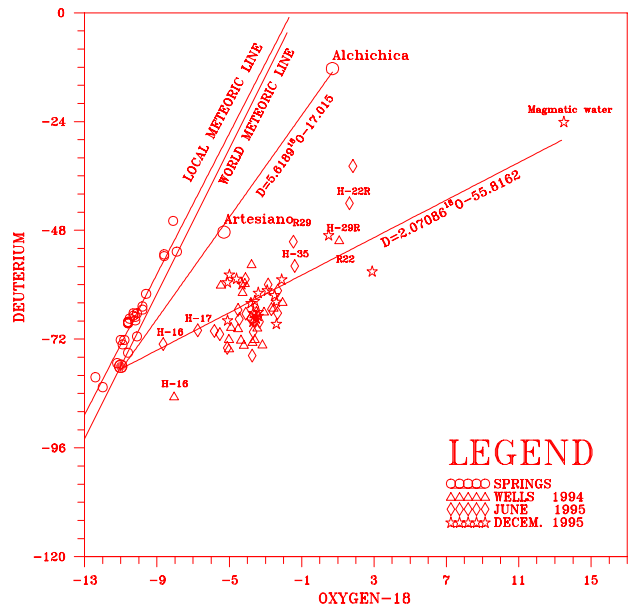


Fig. 7. Deuterium versus oxygen-18 contents for waters from the Los Humeros, Mexico, geothermal field.

Table 1. Chemical composition of separated water from the Los Humeros geothermal field.

Wells No	Date dd/mm/yy	Enthalpy KJ/kg	Elect. Cond. µmhos/cm	Orifice mm	pH	The concentrations are given in mg/l										
						Na	K	Ca	Mg	Cl	SO ₄	HCO ₃	B	SiO ₂	Li	As
H-1	04-Jan-96	1179	1270	50.8	8.3	267	45	2.04	0.119	90.2	233	162	218	1005	0.47	2.79
H-3	05-oct-94	-	1420	50.8	8.2	420	49	1.60	0.019	174.8	71	334	477	556	1.60	4.00
H-6	04-Jan-96	2441	780	63.5	8.1	142	31	1.60	0.180	104.1	23	48	345	946	0.42	27.41
H-7	04-Jan-96	-	950	127.0	7.6	177	36	2.24	0.180	83.3	239	34	946	915	0.41	8.50
H-8	04-Jan-96	1981	1150	76.2	8.1	243	48	2.04	0.219	76.3	213	139	453	1120	0.30	3.10
H-9	03-Jan-96	2726	1160	127.0	7.5	250	52	2.08	0.080	50.3	89	122	1823	838	0.49	73.62
H-10	19-jul-89	2662			6.0	142	19	1.80	0.400	982.7	33	28	1716	909	0.83	N.A.
H-11	05-Jan-96	-	1030	50.8	7.9	207	32	2.56	0.160	74.5	113	156	443	844	0.45	7.60
H-12	04-Jan-96	-	530	50.8	7.6	87	19	0.22	0.119	41.6	12	11	695	688	0.30	16.35
H-13	05-oct-95	1332	2300		8.4	341	54	3.61	0.070	140.1	409	117	219	1006	1.37	N.A.
H-15	03-Jan-96	2551	540	76.2	8.3	113	21	1.20	0.219	6.9	30	61	200	797	0.39	0.50
H-16	06-Jan-96	-	2400	76.2	9.0	549	24	1.20	0.080	4.1	408	216	402	580	0.45	7.90
H-17	03-Jan-96	-	500	50.8	7.8	91	19	1.40	0.160	24.3	91	55	333	893	0.37	24.41
H-18	13-oct-89	1747	1645	50.8	8.0	123	23	0.92	0.04	112.3	43	397	118	229	0.37	N.A.
H-19	05-Jan-96	2141	700	63.5	6.9	140	21	2.18	0.141	23.8	112	57	1873	486	0.41	21.71
H-20	09-Jan-96	-	760	50.8	7.9	160	20	1.80	0.180	114.5	35	20	447	838	0.40	5.53
H-23	13-nov-87	2064	2700	50.8	6.3	290	22	37.00	0.401	622.0	57	21	194	114	0.40	
H-24	18-may-89	2491	1500	38.1	7.6	285	46	1.50	0.109	324.6	27	58	423	406	0.90	
H-27	14-feb-89	2314	1025	76.2	7.4	68	3	1.80	0.4	232.8	26	14	136	100	0.17	
H-28	05-Jan-96	-	1000	50.8	8.7	228	19	0.60	0.299	7.6	56	267	67	424	0.46	1.90
H-29	10-Jan-92	-	220		6.6	220	6	0.20	0.001	36.0	21	17	513	80	0.03	
H-30	03-Jan-96	-	820	50.8	7.8	205	29	1.74	0.160	9.7	39	55	1203	747	0.44	37.31
H-31	08-Jan-96	2689	530	76.2	8.3	115	21	2.00	0.119	8.3	16	16	421	869	0.38	7.60
H-32	05-Jan-96	-	380	50.8	7.6	64	12	0.22	0.241	26.8	23	38	592	710	0.24	18.71
H-33	03-Jan-96	-	2300	76.2	7.7	363	33	2.24	0.141	399.6	49	13	978	458	0.47	29.51
H-34	05-Jan-96	2436	830	38.1	8.5	177	24	1.00	0.080	9.0	91	67	202	1130	0.30	0.50
H-35	09-Jan-96	-	340	63.5	5.8	30	5	1.60	0.100	1.4	43	80	2930	231	0.19	10.60
H-36	08-Jan-96	2663	5500	44.4	6.8	1201	52	3.16	0.520	60.4	1133	3498	3169	16	0.50	0.50
H-36	08-mar-96	2663	1330	44.5	7.6	266	17	2.40	0.321	10.6	300	347	1864	304	0.48	6.44
H-37	11-mar-96	2547	2500	50.8	8.2	466	56	4.60	0.010	4.3	407	102	1660	594	0.47	0.96

Table 3. Chemical composition of gases from Los Humeros geothermal field. On water-free basis, in mmol/mol. Where Pc is the wellhead pressure. Ts is the separation temperature and Cg is the gases total content on water-free basis.

Well No	Date dd/mm/yy	Pc Kg/cm ²	Ts °C	Cg	CO ₂	H ₂ S	NH ₃	He	H ₂	Ar	N ₂	CH ₄	HCl ppm	HF ppm
H-1	140494	9.2	176	17.7	982.1	10.9	2.00	0.0128	1.16	0.02	2.33	1.56	416.3	57.1
H-3	130494	3.2	91	34.3	935.0	27.5	5.02	N.D.	7.50	0.30	21.90	2.72	239.3	219.6
H-6	140494	29.2	186	21.5	910.1	58.6	5.02	N.D.	5.59	0.09	3.69	16.89	112.8	58.0
H-7	140494	13.2	177	11.2	928.2	50.5	4.15	0.01017	4.54	0.12	9.34	3.14	32.7	24.1
H-8	140494	12.2	179	17.4	946.5	36.9	2.12	0.00718	3.66	0.11	6.27	4.43	209.8	54.1
H-9	140494	18.0	206	11.0	857.4	70.3	9.80	N.D.	14.00	0.30	14.54	33.69	18.0	33.6
H-11	140494	14.4	196	21.0	962.4	25.6	2.31	0.00945	2.12	0.05	3.31	4.26	195.0	36.2
H-12	140494	11.3	182	40.5	921.1	40.0	2.54	0.0000852	6.55	0.03	2.82	27.04	313.0	72.5
H-15	130494	16.2	201	18.5	863.5	73.2	5.29	N.D.	12.30	0.26	6.39	39.14	121.0	34.0
H-16	130494	14.8	178	8.1	868.3	90.4	3.11	N.D.	8.20	0.16	7.60	22.21	136.0	43.8
H-17	140494	22.2	198	11.6	913.8	59.0	5.67	0.00442	4.50	0.08	4.37	12.51	195.0	73.6
H-19	120494	20.1	205	15.4	958.8	33.0	2.30	0.00778	1.58	0.03	3.65	0.58	62.2	54.3
H-20	120494	42.3	203	24.7	897.0	70.0	4.02	N.D.	5.85	0.08	4.18	18.89	32.7	47.2
H-28	140494	13.4	192	18.1	958.3	24.7	3.98	0.00405	2.72	0.05	3.41	6.79	224.5	32.1
H-30	130494	13.4	192	8.7	820.3	123.0	7.06	N.D.	11.48	0.29	12.56	25.23	224.5	61.3
H-31	130494	21.9	192	14.9	870.5	73.2	3.72	N.D.	10.73	0.20	7.97	33.68	62.2	20.3
H-32	140494	19.8	203	10.6	914.2	61.0	3.61	0.00268	4.13	0.08	3.84	13.12	298.3	36.9
H-33	130494	11.1	179	8.1	864.4	90.5	8.06	N.D.	9.11	0.24	10.28	17.46	313.0	70.3
H-34	120494		166	22.6	969.4	18.5	2.66	0.00751	1.98	0.03	2.60	4.81	3.0	58.7
U-2	140494		179	11.7	936.3	45.6	4.73	0.00664	3.54	0.10	7.36	2.38	77.0	34.9
U-3	150494		181	18.4	901.5	56.6	2.70	N.D.	7.26	0.05	3.27	28.69	372.0	63.8
U-4	130494		176	5.7	851.7	104.2	6.70	N.D.	8.14	0.23	8.29	20.75	209.0	51.7
U-5	130494		180	16.0	872.4	73.2	3.80	N.D.	10.37	0.19	6.90	33.15	3.3	56.5
U-7	140494		175	7.9	919.7	57.9	5.10	0.00531	3.56	0.06	3.66	9.98	165.5	25.7