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GEOCHEMICAL MONITORING PRACTICES IN COSTA RICA

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ABSTRACT

The geochemical group of the Geosciences Area is involved in the different phases of the geothermal task. Several programs have been established in order to get better knowledge of the different processes that occur during the field exploitation and deep well drilling. The Miravalles geothermal field at this moment is under exploitation and it is generating 150MW although the installed capacity is 163 MW. At this moment in the Pailas geothermal field we are drilling deep wells for production and re-injection and the power plant and facilities are under construction.

In this paper some of the most common practices are mentioned in order to explain how we are working and what the main purpose of each control is.

1. INTRODUCTION

The main geothermal activities that our institution is doing at this moment are the following:

1) Exploitation of the Miravalles field.
2) The development of the Pailas field.
3) The reconnaissance study of the Poco Sol area.
4) The feasibility study of Borinquen.

The first three activities are currently in process and the fourth one will continue once the development of the Pailas field is completed.

The location of each geothermal area can be observed in Figure 1 and most of them are located in the north-western part of Costa Rica, in the Guanacaste Province. The Miravalles geothermal field is an active hydrothermal area confined to a caldera-type collapse structure with a 15 km diameter. This system is a typical high temperature liquid-dominated reservoir, with temperatures declining to the south. The installed capacity is 163 MW, integrated by two units of 55 MW, one of 29 MW, the other of 19 MW and finally one of 5 MW; the first three plants are a condensing plant the fourth is binary plant and the last is a back pressure plant.

Most of the fluids discharged by the Miravalles wells are sodium chloride rich (70-80 %), pH neutral, with total dissolved solids (TDS) about 7,000-8,000 ppm and silica content around 550-650 ppm at atmospheric pressure. But there are two other different types of waters discharged in the Miravalles field; one is discharged by Wells PGM-02, PGM-06, PGM-07 and PGM-19 which are a sodium chloride sulphate water, with a pH in the range of 2.4 and high sulphate concentration of about 535 ppm. Another type is the sodium chloride bicarbonate water discharged by wells PGM-29, 35 and 55. The location of these areas is observed in Figure 2, the wells inside of the yellow area produce neutral fluids, 22 of them are used as production wells, 6 as monitoring wells, 3 are non productive wells and 2 have stopped after 10 years of production. In the red zone 5 wells were drilled and all produce acidic fluid, 3 of them are used as production wells, one as a reserve and 1 is a non productive well. The wells located in the brown area produce sodium chloride bicarbonate water with a high content of non condensable gases, at this moment only 1 are used for production and 2 for reinjection, the area is under study.

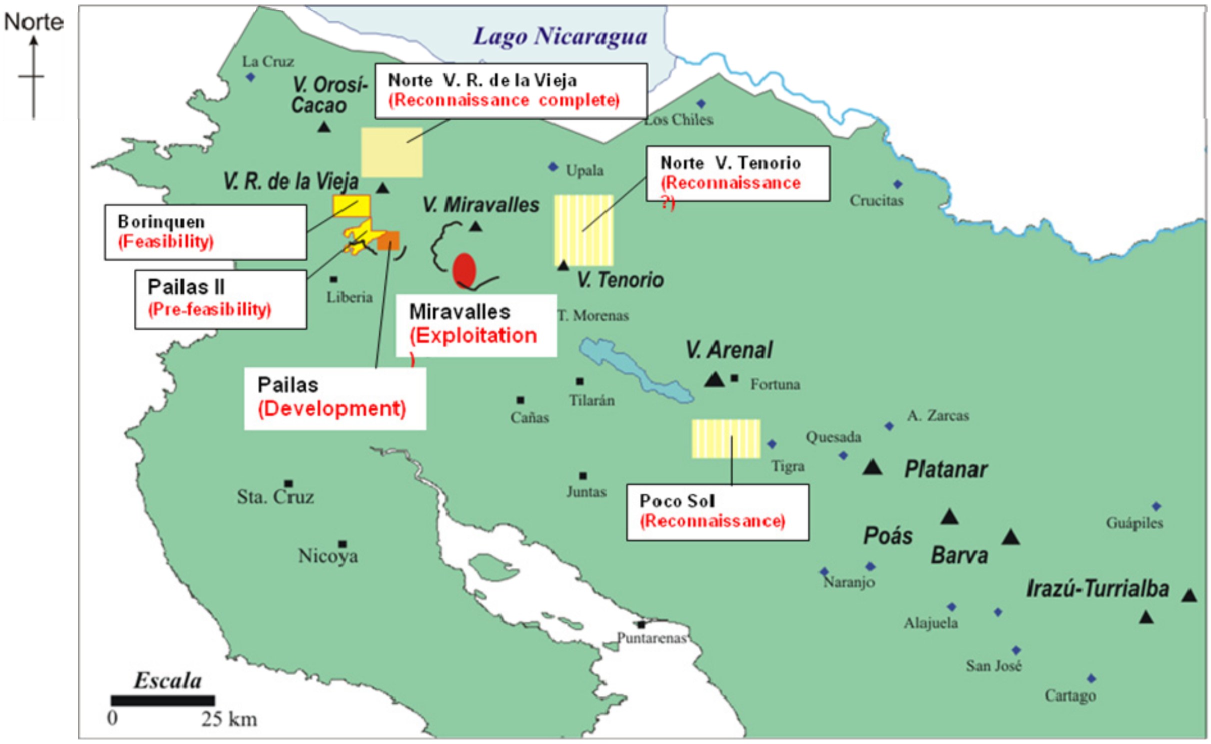

FIGURE 1: Location map of geothermal areas under study in Costa Rica

The Pailas geothermal field is located in the slopes of the Rincon de la Vieja – Santa María volcano complex. At this moment there are 9 wells drilled and 2 are in the process of being drilled (PGP-12 and 24). At this moment a 35 MW binary power plant is under construction, this plant required 89 kg/s of steam and 378 kg/s of brine.

2. DEVELOPMENT PHASE MONITORING

During the well drilling process the geochemical area analyzes the drilling fluids in order to get information about the chemical composition of the aquifers that can be intercepted by the perforation, also these studies can provide information on the existence of pollutants which are affecting the properties of fluids. This knowledge allows us to determine if the reservoir aquifer was intercepted and can obtain information about the deep temperature by geothermometry. This data could be used with the other parameters to stop or continue with the perforation, to get a better knowledge of the hydrology of the system and to improve the conceptual model.

For this analysis we require two samples, one before the drilling fluid goes inside the well and another when the fluid exits the well and by analysis comparison it is possible to determine if an aquifer has

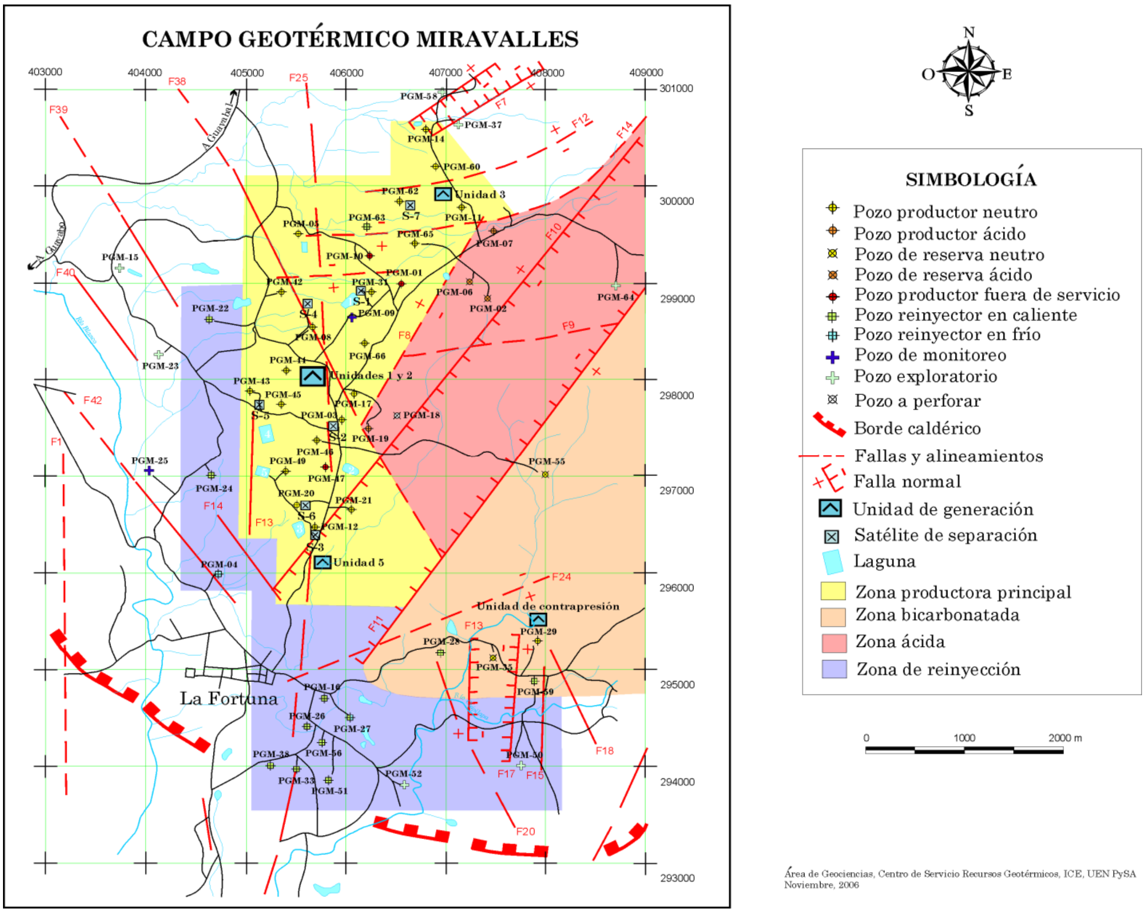

FIGURE 2: Location of the wells in Miravalles geothermal field, Costa Rica

been intercepted or if the fluid is contaminated. Usually we make pH, and conductivity measurements to each sample and analyzed the chloride concentration, if the data are higher, sodium and potassium analysis are included, all depend of the criteria of the geochemist responsible for this process. The labelled sample should indicate the date, the depth, the additive used in the fluid, the source and the temperature.

3. EXPLOITATION PHASE MONITORING

Several programs have been established in the Miravalles geothermal field in order to control:

- The inhibition of the neutral wells.
- The neutralization of the acid wells.
- The evolution of the reservoir to the production load.
- The quality of steam delivered to the power plant.

3.1 Inhibition

A geothermal field with the levels of calcium carbonate encrustation as is in Miravalles would be technically and financially unsustainable without a system of inhibition by inhibitor chemical injection, since the wells would clog in a few weeks (Figure 3), which would require constant cleaning by chemical or mechanical means. The effectiveness of a control system inhibition of calcium carbonate encrustation and studies of inhibitor dose update is an ongoing process and changes depending on the individual development of each well.

FIGURE 3: Calcium carbonate encrustations, PGM-01 Miravalles

For effective control of calcium carbonate inhibition systems weekly sampling must be conducted at each well, which consist in three samples of the liquid fraction taken at atmospheric pressure and with a separation time of ten minutes. In all the samples they should be determining the content of calcium and chloride, and once a month the bicarbonates content (see Table 1).

TABLE 1: Parameters and species measured for the inhibition control in well PGM-49, Miravalles

Fecha	Hora	Regist.	Ca+2	Cl-	Rel.	PC	Ap. Val	Qp	Qb	Inhib.	Densidad	Dosis	T100	Unid.	HCO_3^-
			ppm	ppm		b.a	%	kg/s	L/h	% p/p	dilución	ppm	seg	Inhib.	ppm
07-Sep-09	10:10	4855-09	96	4122	69,9	8,1	54,0	64,6	1,99	20,00	1,020	1,75	124	13,3	
07-Sep-09	10:20	4856-09	96	4126	69,7	8,1	54,0	64,6	1,99	20,00	1,020	1,75	124	13,1	112,0
07-Sep-09	10:30	4857-09	94	4107	68,7	8,1	54,0	64,6	1,99	20,00	1,020	1,75	124	12,1	114,0
		Prom.	95	4118	69,4								Prom.	12,8	113,0
14-Sep-09	09:45	4990-09	95	4056	70,3	8,0	54,0	64,6	1,99	20,00	1,020	1,75	124	13,7	
14-Sep-09	09:55	4991-09	96	4069	70,5	8,0	54,0	64,6	1,99	20,00	1,020	1,75	124	13,9	
14-Sep-09	10:05	4992-09	96	4032	71,2	8,0	54,0	64,6	1,99	20,00	1,020	1,75	124	14,6	
		Prom.	95	4052	70,7								Prom.	14,1	
21-Sep-09	10:40	5110-09	96	4145	69,5	8,2	54,0	64,6	1,99	20,00	1,020	1,75	124	12,9	
21-Sep-09	10:50	5111-09	95	4124	69,1	8,2	54,0	64,6	1,99	20,00	1,020	1,75	124	12,5	
21-Sep-09	11:00	5112-09	96	4143	69,5	8,2	54,0	64,6	1,99	20,00	1,020	1,75	124	12,9	
		Prom.	96	4137	69,4								Prom.	12,8	

3.2 Neutralization

Due to the highly corrosive characteristics of acidic fluids, the pH of these fluids should be altered at depth in order to integrate these wells into the production net and causing the least harm to the system. Without a neutralization system, wells with acidic fluids would be discarded for commercial use.

The effectiveness of control system neutralization of acid is an ongoing process and changes depending on the individual development of each well.

To control the effectiveness of neutralization systems, two samplings per week should be made in each well of the liquid fraction at atmospheric pressure. The first must be by triplicate, while the second duplicate. In both cases the time separation between each sample is ten minutes. In all the samples they should be determining the content of chloride, sulfate, calcium, total iron and the pH (see Table 2).

TABLE 2: Parameters and species measured for neutralization control of PGM-02, Miravalles

Fecha	Hora	Regist.	Ca+2	Cl-	Rel	pH	Fe	SO4	Cond.	PC	Qp	NaOH	T500	T100
			ppm	ppm			ppm	ppm	uS/cm	b.a	kg/s	ppm	S	S
14-Sep-09	08:25	4936-09	39	3922	30,1	6,01	0,47	312	12400	6,94	45,2	53	120	11
14-Sep-09	08:35	4937-09	40	3915	30,7	5,62	1,23	324	12480	6,74	46,5			
14-Sep-09	08:45	4938-09	41	3896	31,3	4,59	1,79	300	12450	6,74	46,5			
		Prom.	40	3911	30,7	5,41	1,16	312	12443	6,81	46,1	53	120	11
21-Sep-09	09:20	5065-09	40	4099	29,1	5,64	0,43	314	12940	6,94	45,2	54	117	11
21-Sep-09	09:30	5066-09	39	4058	29,0	5,40	1,05	317	12770	6,94	45,2			
21-Sep-09	09:40	5067-09	40	4088	29,0	5,47	0,82	314	12790	6,94	45,2			
		Prom.	40	4082	29,0	5,50	0,77	315	12833	6,94	45,2	54	117	11
28-Sep-09	08:30	5229-09	38	3930	28,9	5,77	1,09	291	12460	6,84	45,9	53	118	11
28-Sep-09	08:40	5230-09	39	3962	29,2	5,83	1,12	302	12450	6,94	45,2			
28-Sep-09	08:50	5231-09	39	3994	29,0	5,91	1,15	307	12570	6,94	45,2			
		Prom.	38	3962	29,0	5,84	1,12	300	12493	6,91	45,4	53	118	11

3.3 Monitoring of steam quality

The steam quality delivered to the power plants is monitored in order to determine the characteristics of the steam supplied, with the purpose of taking steps to reduce the potential leaching of contaminants and moisture that could cause corrosion in pipes and turbines. This program includes the monitoring of the quality and purity of steam before the turbines; the monitoring of the rate of the non condensable gases (NCG) – steam; the monitoring of the chemical composition of the NCG and the monitoring of the efficiency dehumidifier and the efficiency of steam separation.

For this purpose samples were taken every two weeks. Taking samples condensate (triplicate, with a separation time of 10 minutes) at the entrance and output of the Miravalles I, II and III dehumidifiers.

In all samples, the pH and conductivity must be measured, and the chlorides and sulphates analyzed (Table 3). In the samples from Miravalles III taken in the last week of the month must include sodium, silica and total iron content.

TABLE 3: Parameters and species measured for monitoring of steam quality

Fecha	Sitio	Código	pH	Cond. µS/cm	Cl^- ppm	$SO_4^=$ ppm
14-Jul-09	**ENT–SEC**	3669-09	4,31	82	0,34	ND
14-Jul-09	**SAL–SEC**	3672-09	4,64	84	0,16	ND
03-Ago-09	**ENT–SEC**	4177-09	4,52	81	0,11	ND
03-Ago-09	**SAL–SEC**	4180-09	4,62	82	ND	ND
18-Ago-09	**ENT–SEC**	4468-09	4,68	78	<0.10	<0.10
18-Ago-09	**SAL–SEC**	4471-09	4,75	79	<0.10	<0.10

In order to study the percentage and composition of gases in the vapour, samples must be taken with vacuum tubes in the output of the dehumidifiers; the samples must be taken in triplicate and be made each month, except for Miravalles III, which are carried out at the end of each month and two weeks before.

In all samples the carbon dioxide, hydrogen sulphide, hydrogen, oxygen, nitrogen, argon and methane must be analyzed; and the percentage of NCG with respect to the total mass of steam must be calculated (Table 4).

TABLE 4: Chemical composition of non condensable gases in the steam delivered to Miravalles 2

Fecha	P.Línea bar m	CO2 mmol/kg	H2S mmol/kg	N2 mmol/kg	O2 mmol/kg	Ar mmol/kg	CH4 mmol/kg	H2 mmol/kg	TOTAL mmol/kg	% gases
14-Jul-09	5,20	178,24	1,81	2,65	0,14	0,03	0,11	0,11	183,1	0,80
%, p/p		98,20	0,77	0,93	0,06	0,02	0,02	0,00	100,00	
03-Ago-09	5,20	154,81	1,62	2,36	0,11	0,03	0,10	0,11	159,1	0,69
%, p/p		98,16	0,79	0,95	0,05	0,02	0,02	0,00	100,00	
26-Ago-09	5,20	158,45	1,71	2,52	0,13	0,03	0,11	0,13	163,09	0,71
%, p/p		98,10	0,82	0,99	0,06	0,02	0,02	0,00	100,00	

3.4 Reservoir monitoring

The parameters of a geothermal reservoir's change with time as a result of it exploitation, will cause a pressure decline. The main effects of the pressure drawdown are increased recharge of water into the reservoir, from above, below or laterally, and enhanced boiling in the case of reservoirs with temperatures in excess of 100°C. Pressure drawdown by itself may cause wells to become unproductive but cold water recharge may also do so by condensing steam and, thus, reduce boiling.

The Miravalles monitoring program ha been used from 1994 in order to study the evolution of the reservoir. This program comprises of two parts, one in which the thermo-hydraulic properties are measured, like pressure, temperature, enthalpy and flow rate; and another in which it analyzes and interprets the chemical composition of fluids from the wells over time.

In order to control the evolution of physical properties and the chemistry of the wells in normal production conditions, it raises the total sampling once every four months. They consist of taking gas samples by triplicate with a mini-separator and a duplicate sample of fluid taken at atmospheric pressure; each sample with a time separation of no more than 30 minutes. Usually the samples are taken in April, August and December. Additionally sampling is conducted for acid wells in February, June and October.

During the intervention of a well to its thermo-chemical-hydraulic characterization made each year during the plant maintenance, chemical samples must be taken at the minimum and maximum flow, this sampling campaign is the same as mentioned before. In wells where there is doubt, the geochemist responsible at that moment must define the procedure to follow.

In all samples the following must be determined:

a) Fraction liquid: pH, conductivity, chloride, sulphate, bicarbonate, fluoride, boron, sodium, potassium, calcium, magnesium, iron, silica (total and monomeric), arsenic, total solids dissolved ammonia and hydrogen sulfide.
b) Fraction gas: steam condensate, carbon dioxide, hydrogen sulphide, hydrogen, oxygen, nitrogen, argon and methane.
c) Calculate the percentage of non condensable gas with respect to the total mass of steam.

The principal variable for monitoring studies is time. It is, therefore convenient to present chemical data from discharged fluids as a plot against time where time is on the x-axis and the respective chemical component concentration or ratio on the y-axis (Figure 4 and 5).

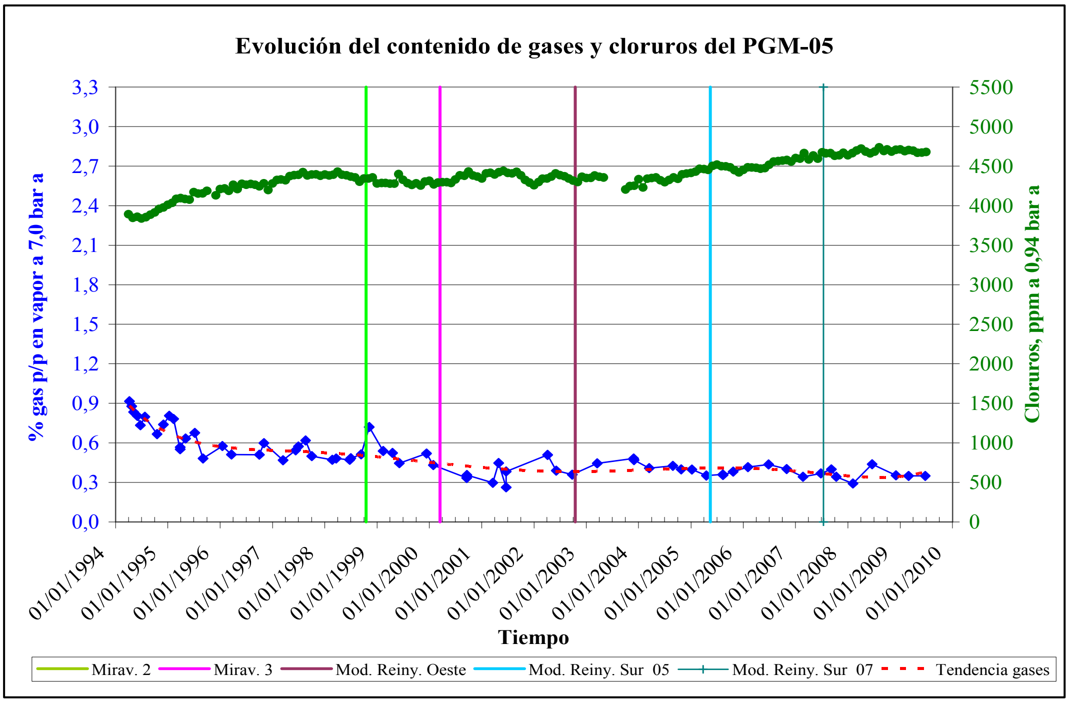

FIGURE 4: Chloride and % non condensable gas evolution in well PGM-05

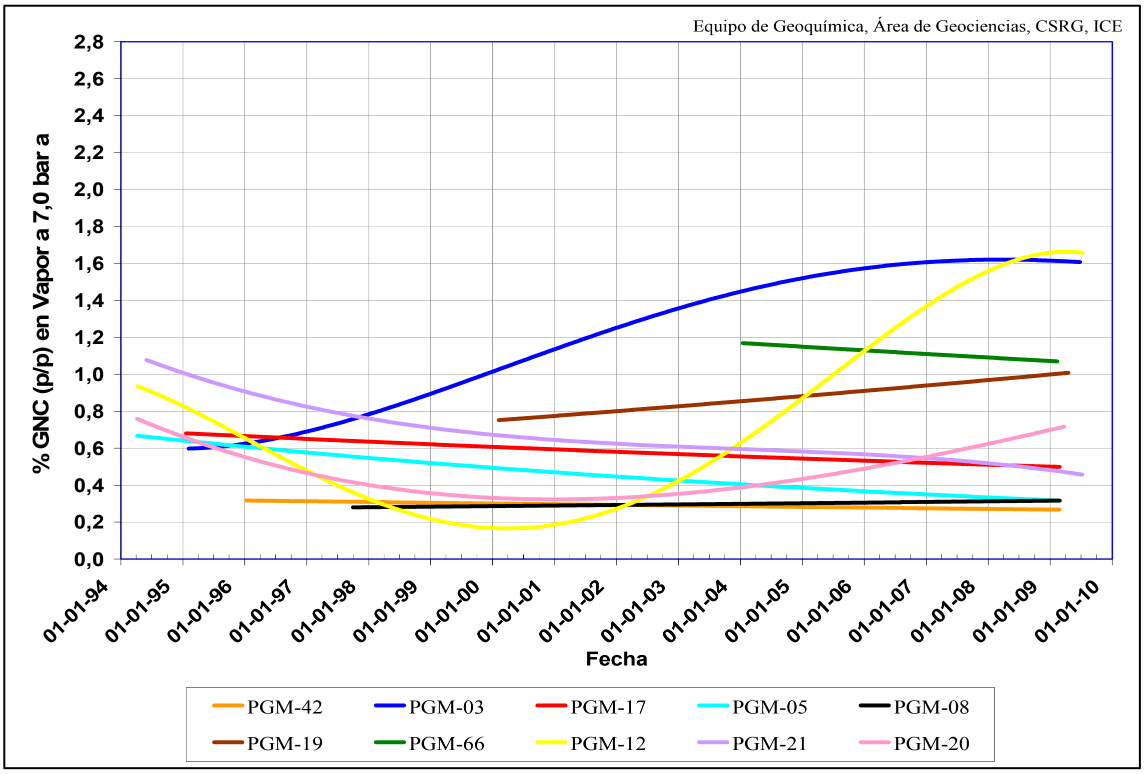

FIGURE 5: Non condensable gases evolution in wells used for Miravalles I

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