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GEOCHEMICAL CHARACTERIZATION AND INTEGRAL ANALYSIS OF DATA LAS PAILAS GEOTHERMAL FIELD, COSTA RICA

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ABSTRACT

This paper presents and discusses the geochemical information obtained in Las Pailas Geothermal Field, corresponding to the characterization of fluids during the development stage, as well as the evolution of the reservoir presented in less than two years of operation. This study focuses on the importance of integrating the information gained from other geoscience areas. This is necessary for the complete characterization of the reservoir and crucial to the detection of problems that occur during evolution, allowing early decisions leading to the sustainability of the field. In this case, geochemical data is integrated with information from Thermal-Hydraulic Studies team

1. INTRODUCTION

Las Pailas Geothermal Field (Figure 1) is located in the Cordillera de Guanacaste in north-western Costa Rica, on the southern flank of the Rincon de la Vieja Volcano. Commercial exploitation of the field began in July 2011 with the first production unit of 35 MWe. Las Pailas II is now being in the process of feasibility with a capacity of 55 MWe.

Las Pailas geothermal field has 20 wells drilled, 9 vertical and 11 directional (Figure 2). The unit Pailas I consists of a combined cycle binary plant for the production of 35 MWe, requiring 80 kg / s of steam and 380 kg / s of liquid and separated at a temperature of 160 ° C. They used a total of six production wells, three hot reinjection wells and two cold reinjection (alternative use), for plant condensate and brine from the lagoon collection. It is reinjected a mass of liquid 380 kg / s at 140 ° C.

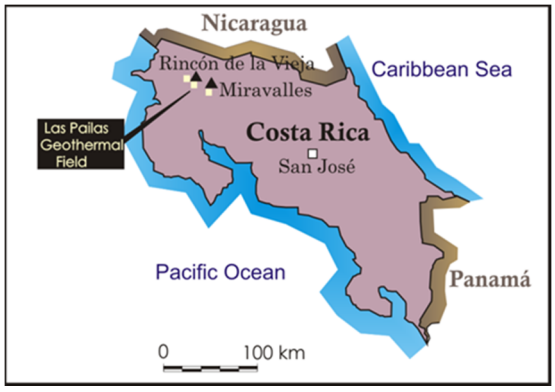

FIGURE 1: Location of Las Pailas Geothermal Field in Costa Rica

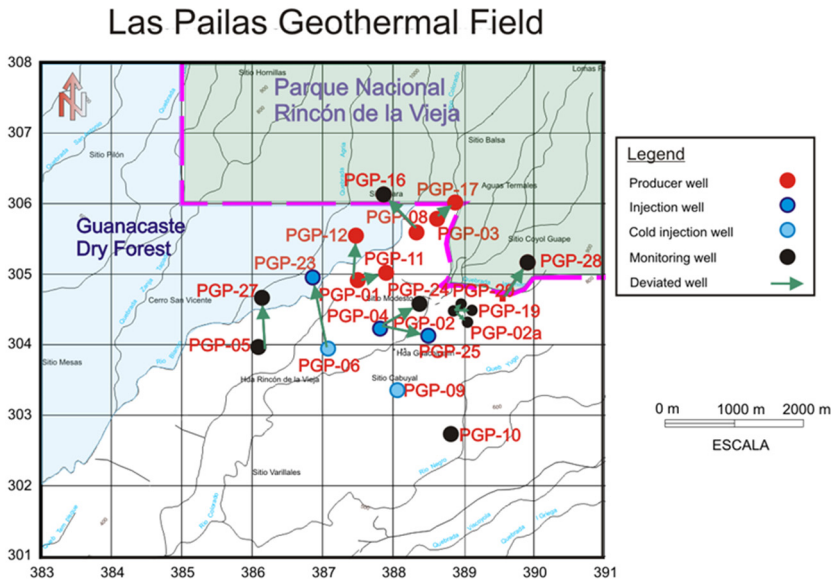

FIGURE 2: Location of the deep wells of Las Pailas Geothermal Field in Costa Rica

During the development stage was determined that the reservoir fluid is liquid dominant. The characterization of the wells in Las Pailas showed they produce fluids from aquifers chemically different as well with different temperature. However it can be said that the main zone fluids, from which they produce are NaCl, neutral, high salt content and with a low content of gases with temperatures ranging between 240 ºC y 255 ºC.

Due to a number of factors, as the location of the reservoir Las Pailas, the "Law of National Parks", permits from the owners of the area and the lack of permeability in peripheral areas, the reinjection zone was located very close to the main producing area. This, coupled with the complex hydrogeology of the system has caused in less than two years of operation of the Geothermal Field Las Pailas, there have been phenomena as a temperatures decrease in both the PGP-24(static conditions) as in the PGP-11 (dynamic conditions). The chemical complexity of the different production zones has not permitted monitor reinjection fluid using the original components of the fluid, this has led to the use of chemical tracers for studies aimed at characterizing hydrogeological system.

Due the above and tracer test results, it has generated the need of moving the reinjection of the central part of the field, to the east side. The migration process will be held in short term and will be implemented through a phased transition. New tracers tests will be held in parallel to obtain information to define the hydrogeology of the system, and thereby define production policies reinjection and ensuring the sustainability of the field.

2. Characterization of fluids of Las Pailas during the development stage

2.1 Liquid chemical composition

The results obtained in the different assessments of deep wells show that the fluid on surface present conductivities between 17000 to 20000 uS / cm. They are sodium-chlorinated, neutral and high salt content. They have values between: sulfate of 41 to 48 ppm; calcium of 129 to 159 ppm and total silica of 642 to 661 ppm for a total of STD of 12100 to 13510 ppm.

It is characteristic of these wells in the early hours of opening produce lower salinity fluids then make this area of higher salinity (20 000 uS / cm). The latter dominates in dynamic conditions, however in

some wells depending on the conditions of production increases or decreases the contribution of one of either zone.

2.2 Calcium carbonate formation

As in the Miravalles Geothermal Field, bicarbonates is the limiting reagent for the formation of calcite fluids in Las Pailas. The contents of bicarbonate on surface in Las Pailas wells have values between 0,1 to 10 ppm. A test on the PGP-08 (well with higher content of bicarbonate in Las Pailas), said that in the current conditions there is not a tendency to form calcium carbonate in fluids from these wells. The test consisted in lowering inhibition system 100 m below the boiling zone injecting water over a period of one month. The capillary tube was then revised and inhibition head, being completely free of deposits. Continue with weekly monitoring of bicarbonates to detect a possible early entry to production zones with higher content of bicarbonates. Currently it is maintained the limit of 10 ppm, above this value there may be risk of calcium carbonate scale formation.

2.3 Chemical composition gas

The vapor of Las Pailas wells is characterized by low-condensable gases. The values are between 0,03 to 0,27.% w/w The C02 represents 99% and values are between 10 to 40 mmol/kg. In the eastern part of the field, sector to which the hot reinjection moved, wells PGP 19 and PGP-20 present a gas content of 0,87 to 1,27 %w/w respectively. The CO2 content of these wells is 140 mmol/kg. This indicates that these two wells are in a different geochemical context than the other wells (Table 1).

TABLE 1: Content gas wells Las Pailas

Well	% GasW/W 5,9 bar absolute
PGP-01	0,10
PGP-03	0,11
PGP-08	0,27
PGP-11	0,03
PGP-12	0,16
PGP-17	0,04
PGP-19	0,87
PGP-20	1,27

2.4 Types of aquifers identified in Las Pailas

The information obtained in the different chemical profiles of wells PGP-04, PGP-01 and PGP-03, revealed the existence in the field of various aquifers with different chemical characteristics. As shown in Figure 3, an aquifer was identified in common in the three wells, this corresponds to higher salinity aquifer containing chlorides between 4700-4800 ppm, its contribution dominates in production conditions. In the upper regions of the wells PGP-03 and PGP-04 presents a lower salinity content aquifer with a chloride content of 4200 ppm, its contribution is more important in static conditions Moreover, only in the PGP-01, in the upper zone has been determined under static conditions an aquifer containing approximately 1000 ppm chlorides and high bicarbonate content. It also identified another aquifer salinity equal to the aquifer present between -300 and -800 m, but different in increased calcium content, it occurs only in the deep zone of PGP-04.

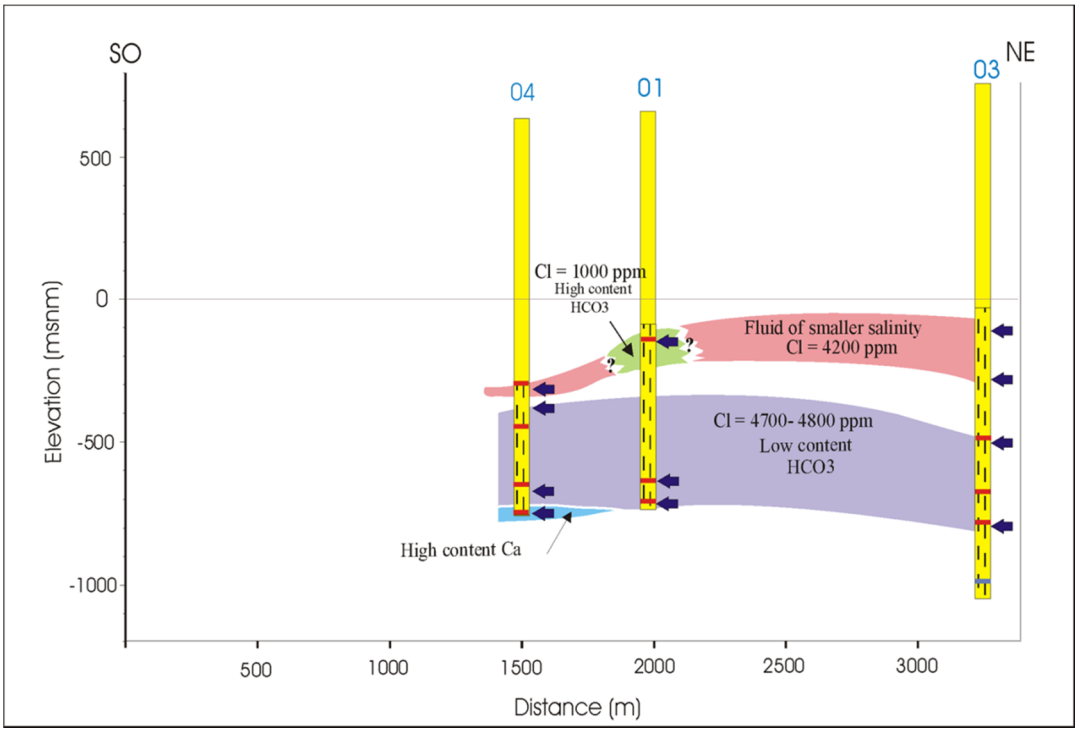

FIGURE 3: Chemical profile showing the different aquifers in the Las Pailas wells

Figure 4 shows a temperature profile measured by the Thermal-Hydraulic Studies team in static condition. It is noted that temperatures show a sharp drop towards the WSW and indicate that the site area comprises wells PGP-02 and PGP-04, while to the area where the wells are located PGP-06 and PGP-05, the conditions thermal strongly decrease. It can also be noted that in the PGP-04 there is a temperature inversion which could indicate that the well is located near the periphery of the reservoir.

Integrating information from chemical profiles downhole with Thermal-Hydraulic Studies team information shows that the contribution of fluids with higher calcium content characteristic of PGP-04, determined only in the depth of the PGP-04, could correspond to the aquifer that causes regression of the temperature which occurs in the well under dynamic conditions such as under static conditions.

Also the integration of this information suggests that the field Las Pailas presents a complex hydrology, wells have input from different aquifers, they have different chemical characteristics and different temperatures, the importance of knowing your existence is on the right track to be implemented, the contribution of these peripherals aquifers can invade at a given time product of exploitation, causing cooling processes and thus decrease production. On the other hand, also the input of another aquifer conditions can cause deposits of calcite saturation, among others, because some of the aquifers characterized are high in bicarbonates.

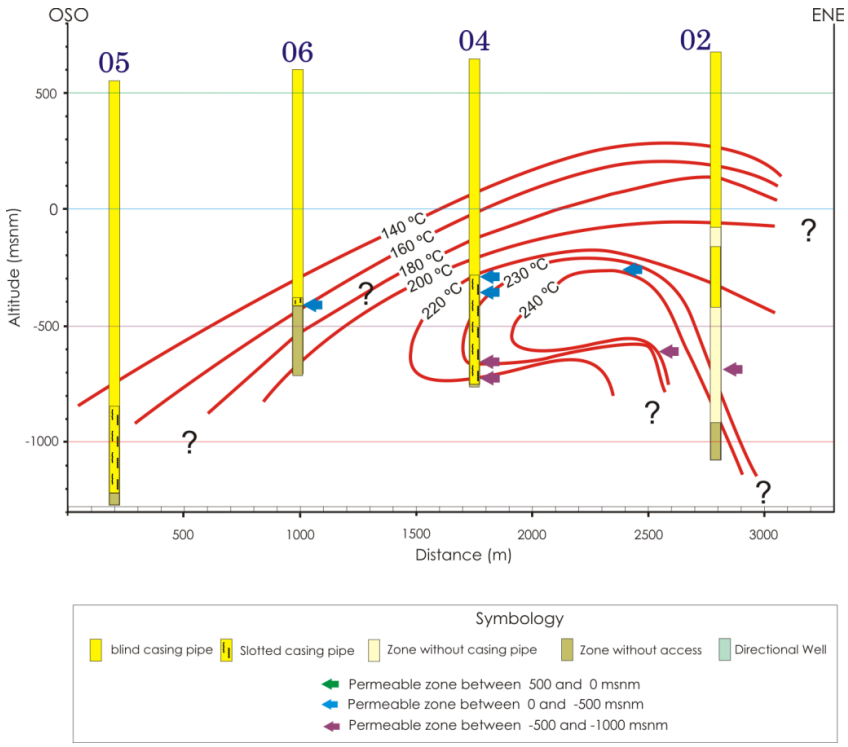

FIGURE 4: Thermal profile oriented WSW-ENE including wells PGP-05, PGP-06, PGP-04, PGP-02

3 Evolution of the fluids in the operating stage

3.1 Geochemical monitoring

Due to the characteristics described above, obtained during the development step, the chemical monitoring of certain chemical components is performed weekly. Additionally total samples are performed (liquid and gas) every three months and thermo-chemical-hydroaulic test assessments every 4 months. Wells static temperature and pressure profiles are performed by Thermal-Hydraulic Studies team every 6 months.

Figure 5 shows the chloride content of all the wells, this component being representative geothermal fluids in both Miravalles as in many other fields in the world has been used as a tracer natural. However, the chemical complexity of the different production zones of the Las Pailas field have not allowed reinjection monitor using original fluid components, so that an increase in chlorides not necessarily indicate return fluid reinjection, because it could be the contribution of one of these aquifers of higher salinity. As part of the detection of the input peripherals characterized aquifer or any other, components that can indicate invasion are monitored. These are: Ca, HCO3, SiO2 and SO4 among others.

3.2 Cooling in static conditions of the PGP-24 Case

Well PGP-24 consists of a directional well producer located in the courtyard of the reinjection zone centre (18,2 m from the reinjection well PGP-04 and 37 m from the reinjection well PGP -25.). It was assigned as a backup producing well. During characterization test produced fluids of: conductivity: 19235µS/cm, chlorides: 6655 ppm; sulphates: 36 ppm and calcium: 133 ppm. The well produced a total flow of 193 kg/s to a temperature measured in static conditions of 247ºC (January 22, 2010).

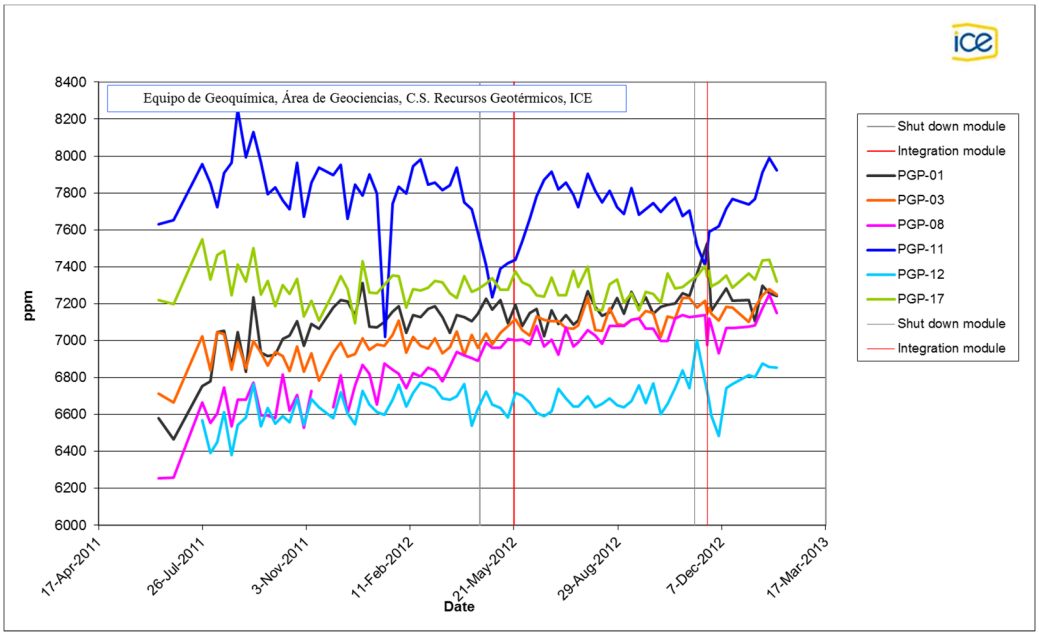

FIGURE 5: Evolution of chloride content in wells Las Pailas

After the entry into production of the unit I, a decrease in static temperature was identified of 247 °C to185°C between 1100 and 1030 m depth. We conducted a production test and initial conditions had changed, the fluids had an increased content of chlorides, sulfates and calcium reaching a value of: Cl: 7091 ppm; SO_4: 166 ppm and Ca: 221ppm. The well production declined in this test produce a total flow of 85 kg/s. Initially it was thought the reason of cooling was reinjection. The increased chloride content supported this hypothesis. However enrichment in calcium and sulphate content not coincide with increasing concentration corresponding to the loss of 20% of the vapor fraction. Subsequently, a series of chemical profiles and temperature profiles (Figure 6) determined that the cooling zone corresponds to the calcium sulphate zone, giving then a movement of fluids.

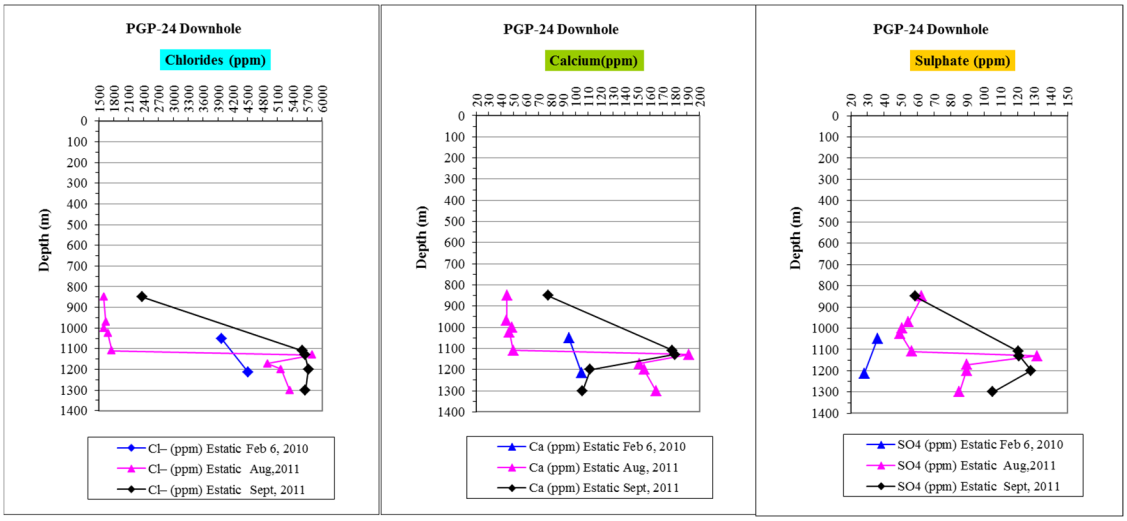

FIGURE 6: Chemical profiles PGP-24. They show increase in Cl, Ca an SO4 after stars Pailas I. The highest concentrations of these components are in cooling zone

3.3 Cooling in dynamic conditions of the PGP-11 case

The PGP-11 well is a production well directional, located 845 m from the well reinyector PGP-04 and 810 m from the reinjection well PGP-25. During characterization produced fluids of: conductivity:

18910 µS/cm, chlorides: 6643 ppm and sulphates and calcium containing: 36 ppm and 139 ppm respectively. The well produced a total flow of 132 kg /s with a temperature dynamics of 254 ºC, after the entry of production unit I, there has been a gradual decrease in temperature dynamics (Figure 7) coming to 213 ° C in the last profile performed the march 11, 2012.

Some chemical variations also presented. The PGP-11 corresponds to the well with higher chloride content in Las Pailas field (Figure 5). With the entry into operation of unit I this well has presented the same trend of a slight increase in chlorides, and also presents decreases in some point relating to production zones of lower salinity. The content of calcium and sulphate show a similar behaviour.
During maintenance of the plant the PGP-25 was pulled from the reinjection system. Parallel to this, the content of Cl andSO_4 showed a tendency of decrease (Figure 8).

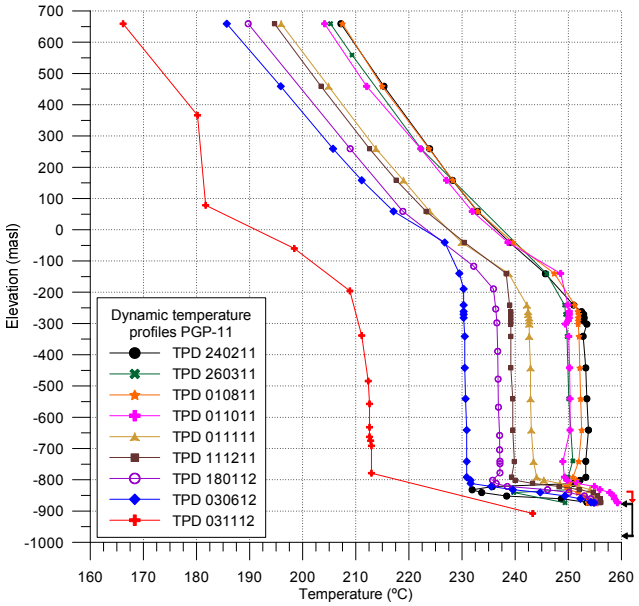

FIGURE 7: Temperature profiles PGP-11

3.4 Results of tracer test

Due to the need to determine if the cause of cooling PGP-11 and PGP-24 were results of reinjection or invasion of another aquifer, and the urgency of know the hydrogeology of the system to define policies reinjection and production, a test tracer was performed by injecting sodium benzoate in the PGP-25, which could be responsible for the effects observed in the wells cited.

The tracer was detected in well PGP-11 twenty four hours after injection of the tracer and maximum concentration was reached after 42 hours (Figure 9), indicating a rapid connection between PGP-11 with the reinjection well PGP-25. In the case of the PGP-24 tracer also appears at 24 hours. The highest concentration of tracer was measured in the zone of 1300 m which does not correspond to the zone of lower temperature. However, because no sampling were realized in the zone characterized as sulphated and low temperature, we cannot determine if this zone had a direct influence from fluid reinjection.

Due to the above and because of the behaviour of temperature increase during the short output when PGP-25 was a reinjection well (Figure 10) it follows that the cooling zone of a PGP-24 was due by a invasion of a peripheral aquifer sulphated. The phenomenon that causes this may be linked to the following hypothesis:

1. That the effects of reinjection in the PGP-25 create conditions so that this aquifer sulphated lower temperature, with its own characteristics, becomes present.

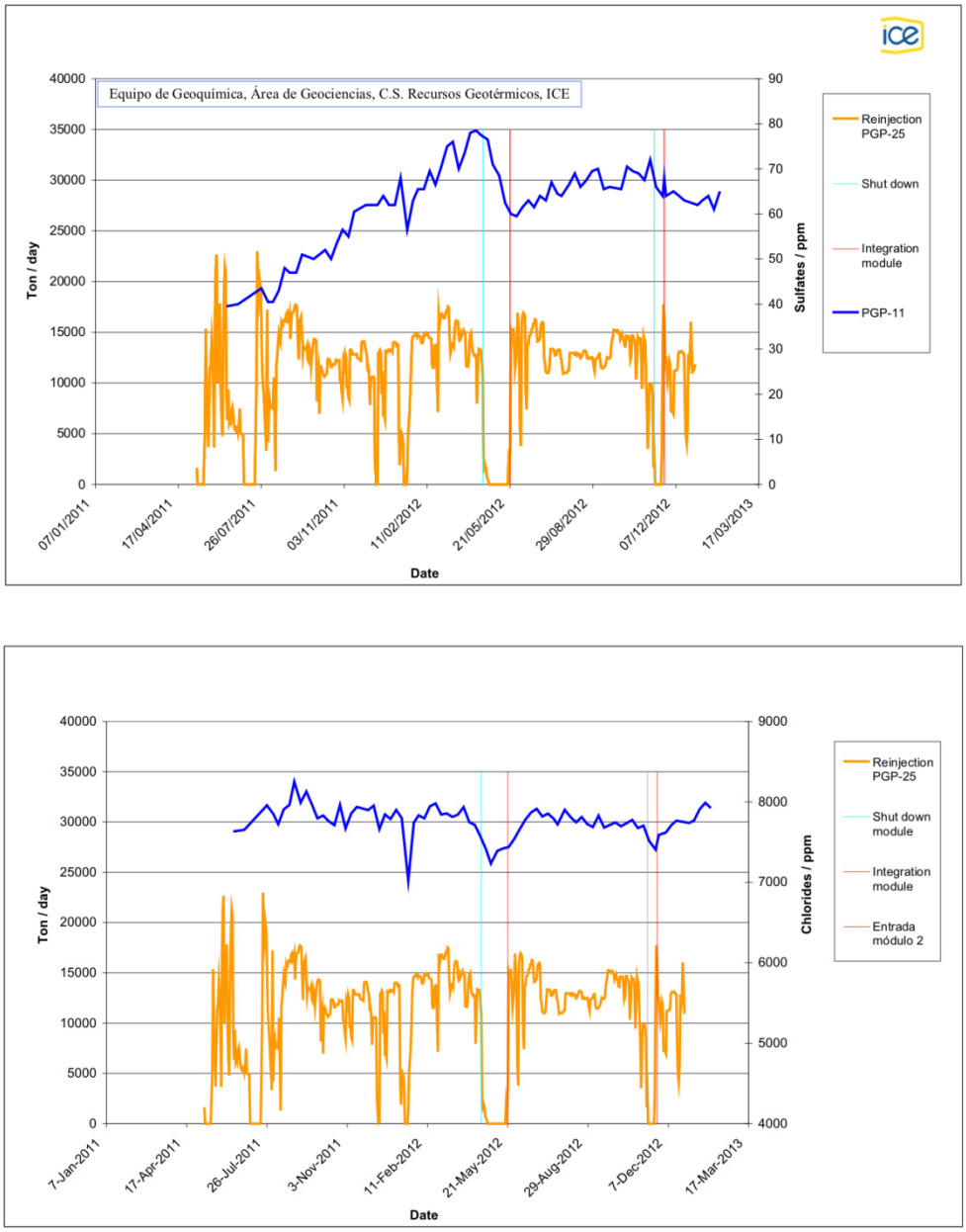

FIGURE 8: Evolution of SO_4 and Cl in PGP-11vrs mass reinjection into the PGP-25

2. Reinjection fluids are passing through an area rich in sulphates and are enriched in this component and the cause of cooling is reinjection that is emerging in this area, either from the PGP-25 or PGP-04.

These hypotheses will be corroborated in a second tracer test.

In the case of cooling the PGP-11, results indicate that the cooling effect could be caused by the reinjection of PGP-25. The information from the tracing test complemented the necessity of moving the reinjection of the central part of the field (PGP-25 and PGP-04) to the east side (PGP-19 and PGP-20). This process will take place in short time. Currently the measures taken were: a) to reduce the mass extraction of the PGP-11 and b) to decrease as much as possible reinjection into the well PGP-25 while running the transfer of reinjection. With the above measures the output of the plant is kept in the 35 MWe for which it was installed.

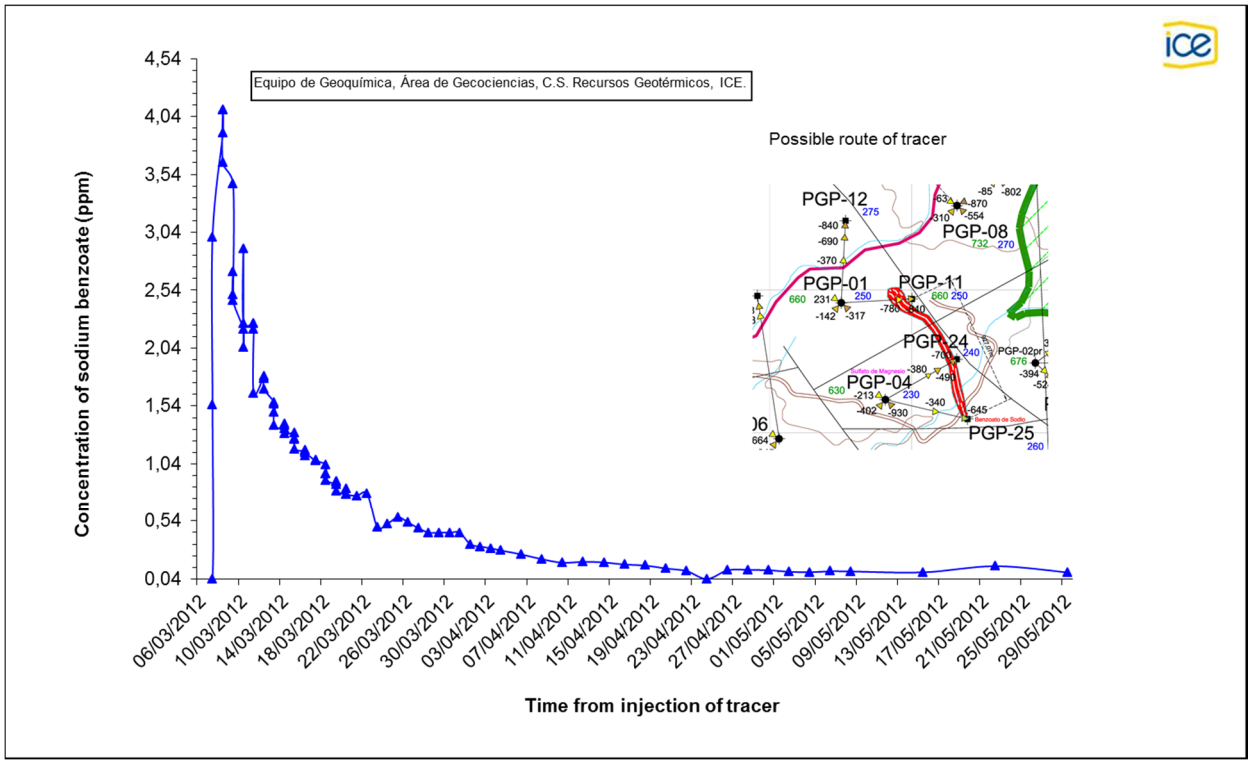

FIGURE 9: Tracer concentration in the PGP-11 (modified from Solis, 2012)

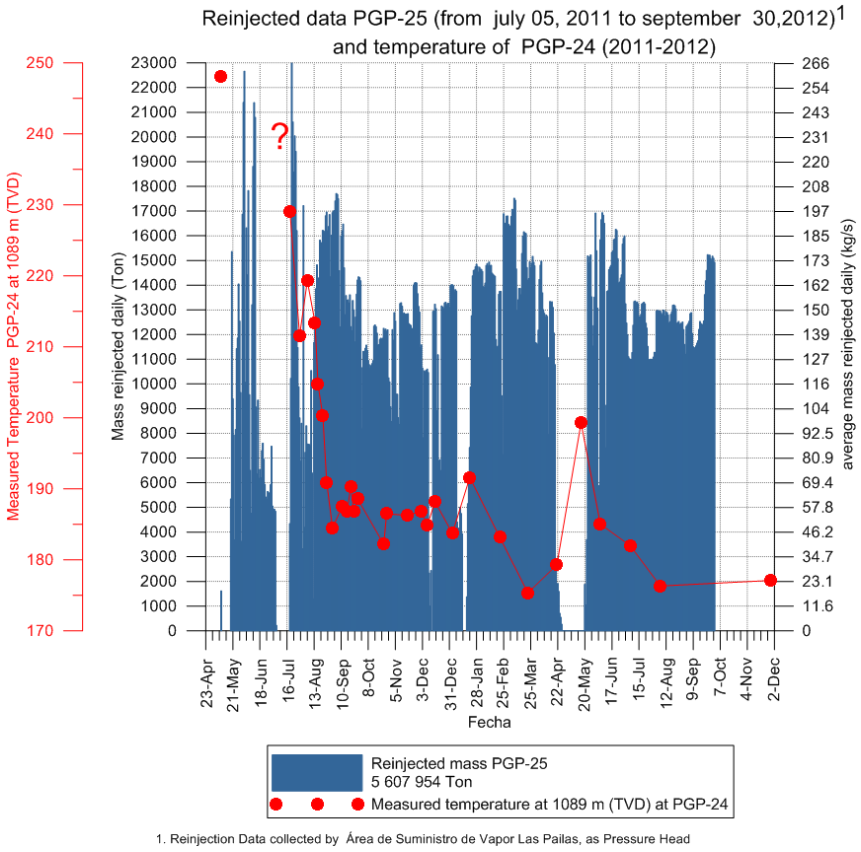

FIGURE 10: Static temperature evolution of PGP-24 and mass reinjection into the PGP-25

4. CONCLUSIONS

The information gained from the characterization of fluids in the stage of development and their integration with other geoscientific areas, allow to create a complete model of the initial conditions and the possible effects that may appear in the exploitation step of the field. This will allow to create a adequate monitoring programme.

Information acquired and the integral analysis of this during exploitation of the field are the key to identify problems and find solutions at an early stage, as invasion of aquifers peripherals, process cooling and other effects product complex hydrogeological conditions.

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