



**HAL**  
open science

# Geochemical monitoring of the thermal manifestations located near the Bouillante geothermal power plant, in Guadeloupe (FWI)

Bernard Sanjuan, Michel Brach

► **To cite this version:**

Bernard Sanjuan, Michel Brach. Geochemical monitoring of the thermal manifestations located near the Bouillante geothermal power plant, in Guadeloupe (FWI). Applied Isotope Geochemistry - 11 (AIG-11), Sep 2015, Orléans, France. pp.25-29. hal-01159424

**HAL Id: hal-01159424**

**<https://hal.science/hal-01159424>**

Submitted on 20 Jun 2022

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



11<sup>th</sup> Applied Isotope Geochemistry Conference, AIG-11 BRGM

## Geochemical monitoring of the thermal manifestations located near the Bouillante geothermal power plant, in Guadeloupe (FWI)

Bernard Sanjuan<sup>a</sup>, Michel Brach<sup>b</sup>

<sup>a</sup>BRGM, Direction des Géoressources - Division Géothermie - 3, Av. Claude Guillemin - 45060 Orléans Cedex 02, France

<sup>b</sup>BRGM, Direction des Laboratoires - 3, Av. Claude Guillemin - 45060 Orléans Cedex 02, France

### Abstract

The Bouillante high-temperature geothermal field, 250-260°C, is developed around the Bouillante Bay along the western coast of Basse-Terre Island, in Guadeloupe (French West Indies, FWI). Since 2005, the new geothermal power plant has an installed capacity of 15.5 MWe gross, which represents about 6-7% of the annual electricity needs in the Island. Among the research efforts carried out by the BRGM group and partially funded by ADEME (French Environment and Energy Management Agency), different geophysical and geochemical monitoring methods of the geothermal exploitation have been started, tested and developed<sup>1</sup> in order to optimize and secure electricity production and to control its impact on the immediate environment of the power plant. This is especially important because the power plant is located inside the Bouillante town. Among these methods, this paper presents the main results and conclusions obtained for the geochemical monitoring of the terrestrial thermal manifestations located near the geothermal power plant. This study shows that, except for the “Tuyau” hot water, located inside the main production area and for which the steam contribution increases and salinity decreases when the power plant is in production (decreasing reservoir pressure), no significant geochemical change depending on the geothermal exploitation is observed in the fluids of the other terrestrial thermal manifestations. Consequently, the quality of the thermal waters of the Bouillante area can be considered as not damaged by the geothermal exploitation.

© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the scientific committee of AIG-11

*Keywords:* Bouillante; geothermal field; water; steam; chemistry; isotopes; springs; fumaroles

### 1. Introduction

The Bouillante high-temperature geothermal field, 250-260°C, located in the volcanic Basse-Terre Island, Guadeloupe (FWI; Fig. 1), is the only French field of this type. It is currently being exploited by Géothermie Bouillante, a subsidiary of BRGM and EDF. Since 2005, the new geothermal power plant is constituted of two units with an installed capacity of 15.5 MWe, which represents about 6-7% of the annual electricity needs in the Island.

The maximum discharge of geothermal fluid is close to 600 tons/h, among which 120 tons/h of steam for electricity production. Presently, only BO-5 and BO-6 are producer wells. BO-4 and BO-7 are observation wells (Fig. 2).

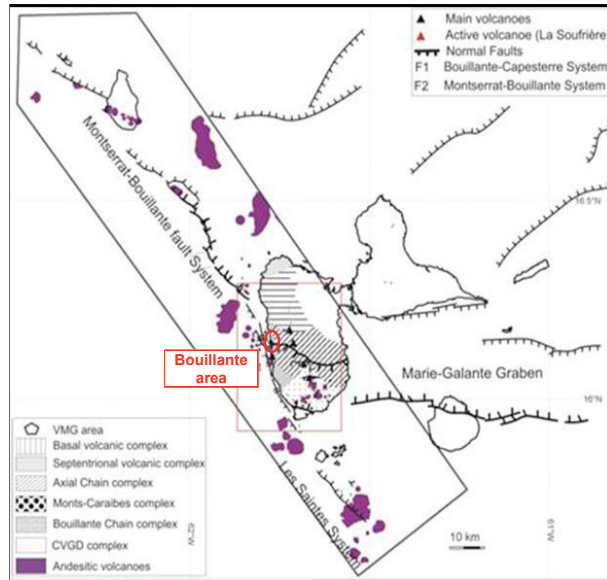


Fig. 1. Bathymetric and tectonic map of the Guadeloupe Archipelago (FWI). Location of the Bouillante area.

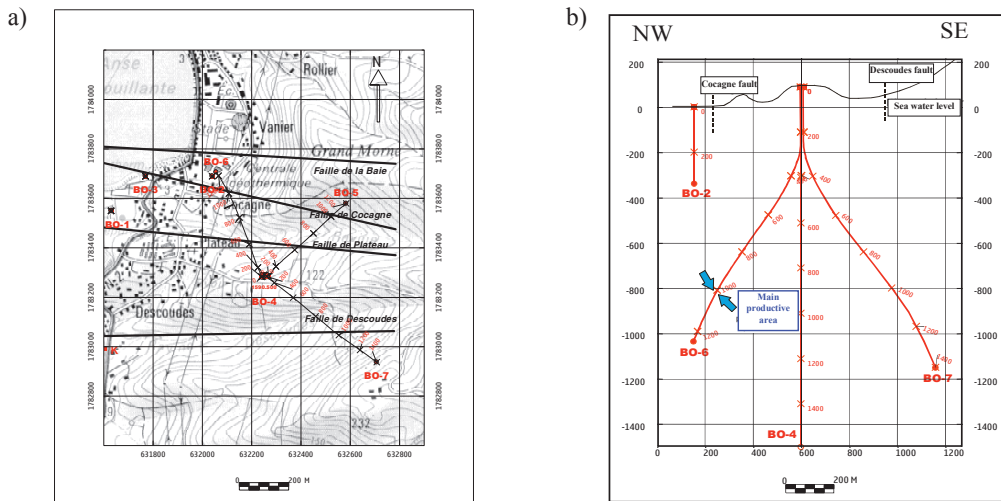


Fig. 2. a) Location of the Bouillante geothermal wells. Projection at surface of the wells BO-5, BO-6 and BO-7. b) Vertical NW-SE cross-section showing the vertical wells BO-2 and BO-4 and the deviated wells BO-6 and BO-7. BO-5 is in a perpendicular plan (figures from CFG Services).

In the framework of the research carried out by the BRGM group and co-funded by ADEME, it was decided to initiate, test and develop different geochemical and geophysical monitoring methods of geothermal exploitation in a volcanic island context such as that of Guadeloupe<sup>1</sup>. These methods facilitate optimization of the exploitation and the life span of the Bouillante field, securing electricity production, and controlling its impact on the immediate environment of the power plan. Among these methods, this paper presents the main results and conclusions obtained for the geochemical monitoring of the thermal manifestations located near the geothermal power plant<sup>1,2,3,4,6</sup> which has been intensified by BRGM in collaboration with CFG Services, since the starting of the new power plant in 2005, with an increased geothermal production by a factor of about 4 compared with the previous production.

## 2. Fluids discharged from the terrestrial thermal manifestations located near the geothermal power plant

Surface thermal manifestations in the Bouillante area are abundant and were recognized in the framework of research works carried out by BRGM in 1996, 1998 and 1999<sup>2,3,4</sup>. Most of them are submarine and scattered at the bottom of the Bouillante Bay<sup>2,3,4,5</sup>. The terrestrial manifestations (fumaroles, thermal springs, hot grounds...) are the expression of a hydrothermal sub-surface system<sup>1,2,3,4,6</sup> associated with main tectonic structures such as the Cocagne fault (Fig. 3), which is the permeable, fractured reservoir zone intersected by the production wells (Fig. 2).

The pressure drawdown within the reservoir was nul or minimal when the first 4.5 MWe-unit was operating. Since 2005, when the second 11 MWe-unit was also put on line, a sharp pressure decline was observed and ranged up to 6 bars. It appears to be closely related to the total mass of extracted fluid (usually > 4 million of tons per year). Consequently, the production must be controlled in order to not increase this pressure decline and a partial reinjection of separated fluids (up to 150 tons/h) has started into the well BO-2 (Fig. 2b), since 2014.

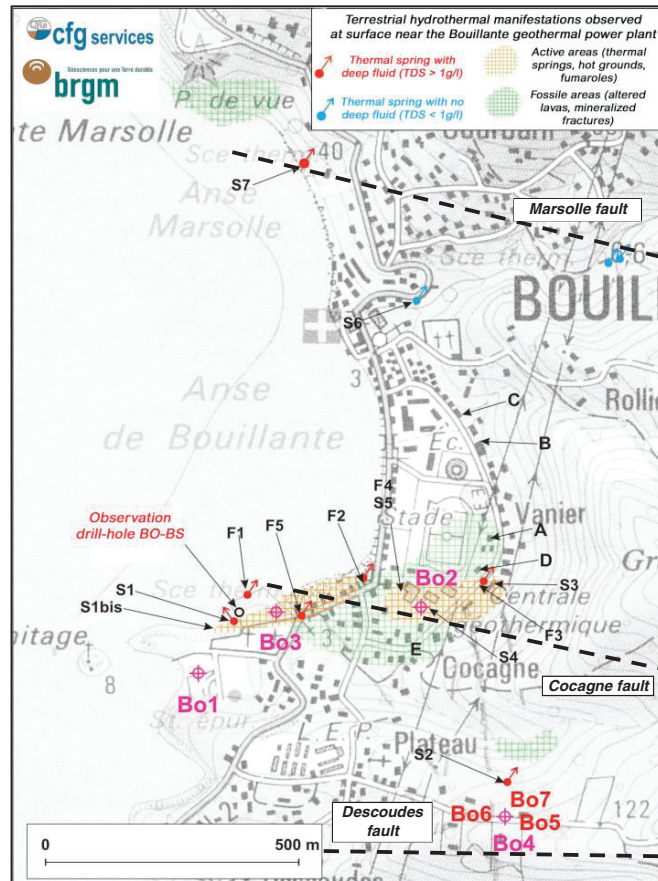


Fig. 3. Area selected for fluid geochemical monitoring of the Bouillante terrestrial thermal manifestations.

Despite this pressure decline, no significant change has been observed on the chemical and isotopic characteristics of the Na-Cl geothermal fluid discharged from the production wells, which is described in detail in numerous publications<sup>3,4,6</sup>. The isotopic signature in  $\delta D$  and  $\delta^{18}O$  of this fluid is estimated to be close to  $-1.1 \pm 0.8 \text{ ‰}$  and  $-1.0 \pm 0.2 \text{ ‰}$ , respectively, and is in agreement with the previous data<sup>1</sup>. As already mentioned<sup>1</sup>, the samples of separated geothermal water and steam indicate different but homogeneous values of  $\delta D$  and  $\delta^{18}O$  following the temperature of phase separation (about 165 and 100°C; Fig. 4a and 4b).

The figures 4a and 4b suggest that, for most of the terrestrial thermal manifestations, their fluids are constituted of a mixing of reservoir geothermal fluid and surface freshwaters at very different proportions. For example, the proportions of geothermal fluid are relatively high (> 45% at least) in the waters of the “BO-BS” drill-hole (S1) or of the “Cave-BO2” thermal spring (S4; Fig. 3). They are much less significant (< 15% at more) in the waters of the “Ravine blanche” (S2), “Tuyau” (S3), “Old football stadium” (S5) or “Marsolle” (S7) thermal springs. In this last one, a small contribution of seawater is also present. No contribution of reservoir geothermal fluid is observed in the water of the “Bouillante river” (S6) thermal spring, which is only warmed by thermal conduction.

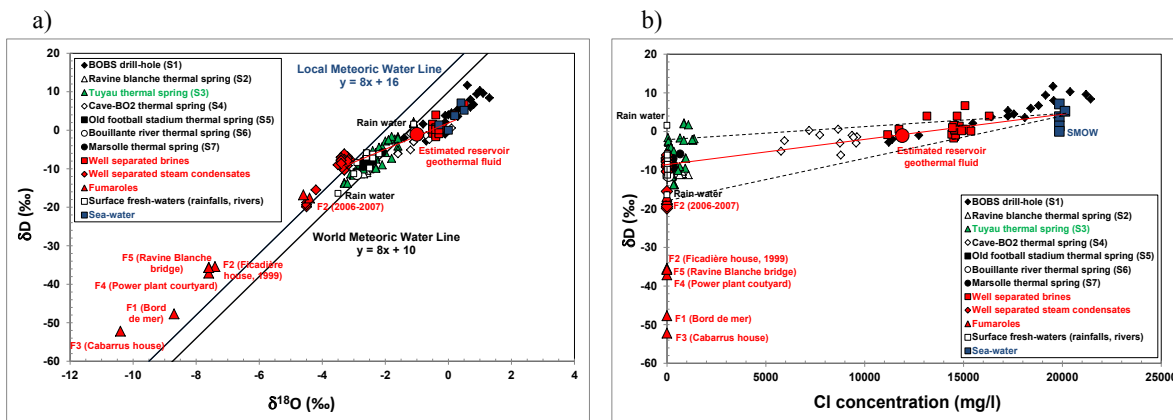


Fig. 4. a) δD versus δ<sup>18</sup>O values for the Bouillante terrestrial thermal manifestations. b) δD values versus Cl concentrations.

The steam of most of the fumaroles (Fig. 3) results from a vaporization phase at about 100°C of a mixture of reservoir geothermal fluid and surface freshwater at different proportions (Fig. 4). For the fumarole F2 sampled in 2006 and 2007, the steam is only constituted of vaporized reservoir geothermal fluid at about 100°C (Fig. 4).

Among these terrestrial thermal manifestations, only the monitoring of the “Tuyau” thermal spring (S3) indicates variations of temperature and chemical and isotopic water composition (Fig. 5a and 5b) associated with the geothermal exploitation. When the geothermal power plant is normally producing, the steam contribution tends to be higher: we can then observe a decrease of water salinity and δD and δ<sup>18</sup>O signature (Fig. 5a and 5b). When the geothermal production is stopped or highly reduced, the steam contribution tends to decrease or even to disappear, causing a significant increase in water salinity and in δD and δ<sup>18</sup>O signature. The progressive increases observed for the δD and δ<sup>18</sup>O values from 1998 to 2002 and from 2005 to 2009, without an apparent increase of water salinity, could be explained by a temperature rise of the steam separation from the geothermal fluid (the isotopic values of steam separated at higher temperatures are closer to those of the geothermal fluid and consequently, less negative).

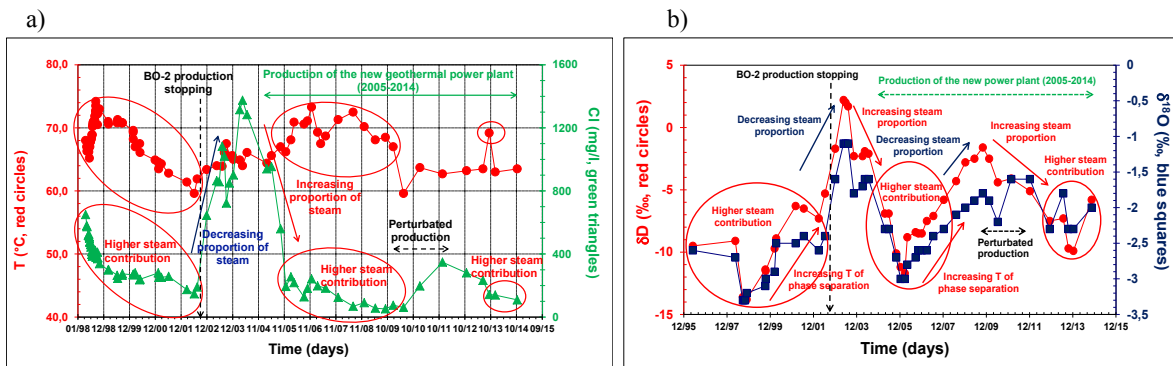


Fig. 5. a) Monitored temperature and Cl concentration of the “Tuyau” thermal spring (S3) versus time. b) δD and δ<sup>18</sup>O values versus time.

The increase of steam contribution in the “Tuyau” thermal spring when the power plant is in production is mainly due to the pressure decrease observed in the geothermal reservoir, which can reach up to 6 bars.

The production fluids are directly discharged in the sea, after a preliminary mixing with large amounts of seawater used for the cooling system of the power plant. As already mentioned, a part of these production fluids is also re-injected into the well BO-2.

### 3. Conclusion

Long-term monitoring is an invaluable tool for the knowledge and modeling of a geothermal reservoir in order to manage resource uncertainties, optimize its development and reduce the impact of its exploitation on the environment. On the whole and despite the sharp pressure decline observed in the geothermal reservoir since 2005, very few changes of the monitored parameters are observed. Among the scarce changes induced by the geothermal exploitation, some variations occur on the temperature and the geochemical composition of the water discharged from the “Tuyau” thermal spring, which is located inside the main production area and is the most tapped zone. These variations are mainly associated with changes of contributions between geothermal steam and water, and surface freshwater, following the exploitation conditions. The increase of steam contribution in the “Tuyau” thermal spring when the power plant is in production is mainly due to the observed decrease of the reservoir pressure. Globally, the quality of the thermal waters of the Bouillante area can be considered as not damaged by the geothermal exploitation.

### Acknowledgements

These research works were co-funded by ADEME through several BRGM-ADEME contracts established between 1999 and 2013. We would like to thank Geothermie Bouillante SA and his staff for site facilities and their help on site. We are also grateful to CFG Services for their collaboration.

### References

1. Sanjuan B., Jousset Ph., Pajot G., Debeglia N., De Michele M., Brach M., Dupont F., Braibant G., Lasne E., Duré F. Monitoring of the Bouillante geothermal exploitation (Guadeloupe, FWI) and the impact on its immediate environment. *Proc. WGC2010, Bali, Indonesia*; 11 p.
2. Sanjuan B. Champ géothermique de Bouillante: synthèse des travaux réalisés avant 1999. *Report BRGM/RC-51673-FR* 2001; 46 p.
3. Sanjuan B., Traineau H., Lasne E. and Brach M. Travaux scientifiques menés par le BRGM et la CFG sur le champ géothermique de Bouillante. *Final report BRGM-CFG* 2002 ; 130 p.
4. Lachassagne P., Maréchal J.-C., Sanjuan B. Hydrogeological model of a high-energy geothermal field (Bouillante area, Guadeloupe, French West Indies). *Hydrogeological Journal* 2009; **17**:1589-1606.
5. Millot R., Scaillet B., and Sanjuan B.: Lithium isotopes in island arc geothermal systems: Guadeloupe, Martinique (French West Indies) and experimental approach. *Geochimica et Cosmochimica Acta* 2010; **74**: 1852-1871.
6. Sanjuan B., Bouchot V., Mathieu F., Jousset Ph., Delatre M., De Michele M., Millot R., Innocent Ch. Travaux de recherche sur le champ géothermique HT de Bouillante, en Guadeloupe (2009-2012). *Final report BRGM/RP-61715-FR* 2013; 192 p