

DEVELOPMENT OF HIGH-TEMPERATURE GEOTHERMAL ENERGY IN THE FRENCH WEST INDIES (FWI)

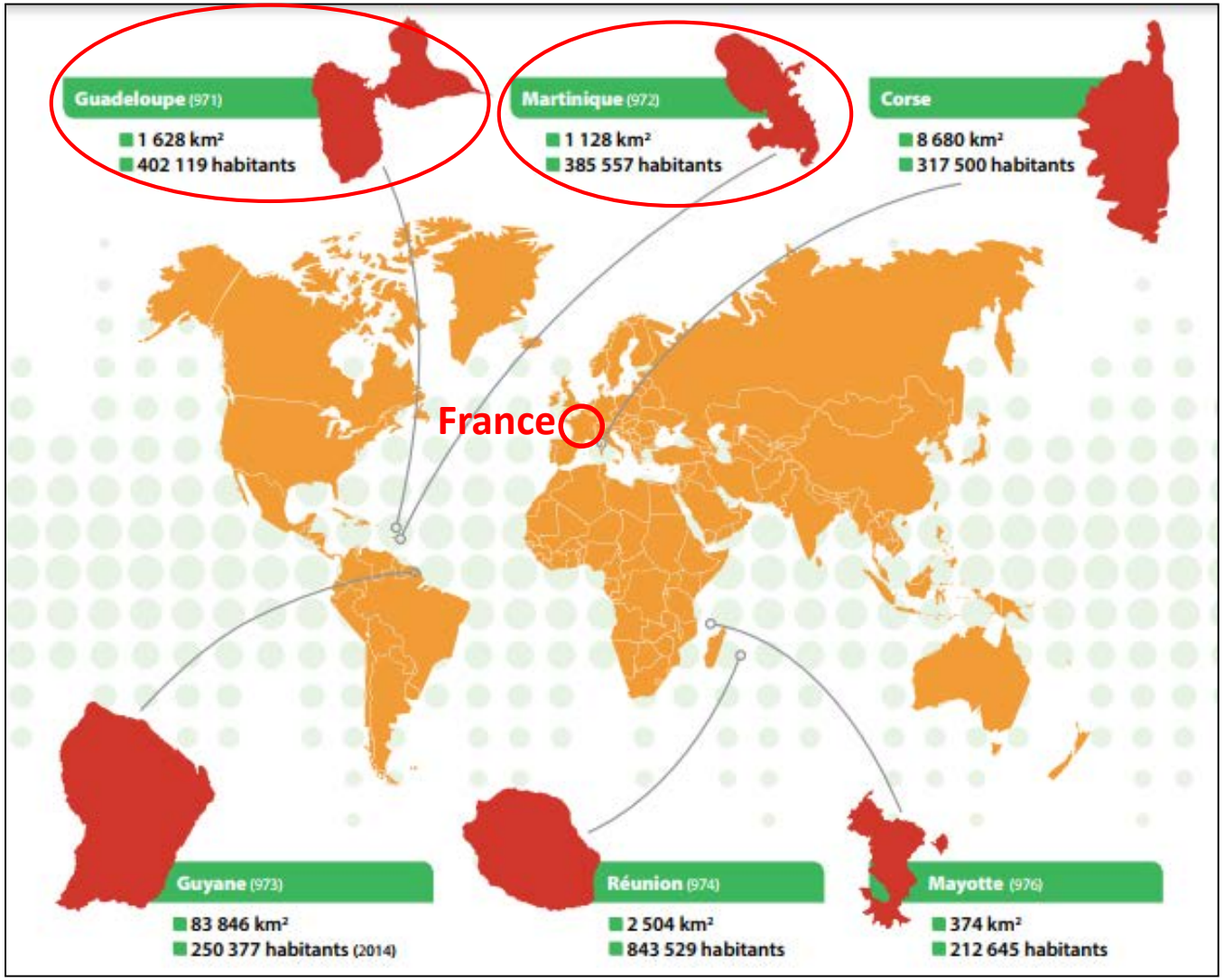
B. SANJUAN (BRGM – GEOTHERMAL DIVISION, GEO-RESOURCE DIVISION)

GEOTHERMAL DHC DIGITAL WORKSHOP « POSSIBILITIES AND LIMITATIONS OF GEOTHERMAL ENERGY USE FOR HEATING AND PRODUCTION ELECTRICITY AT VOLCANIC ISLANDS » - THURSDAY 1ST OCTOBER 2020

INSTITUT CARNOT brgm

Géosciences pour une Terre durable
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FRENCH OVERSEAS DEPARTMENTS (DOM)

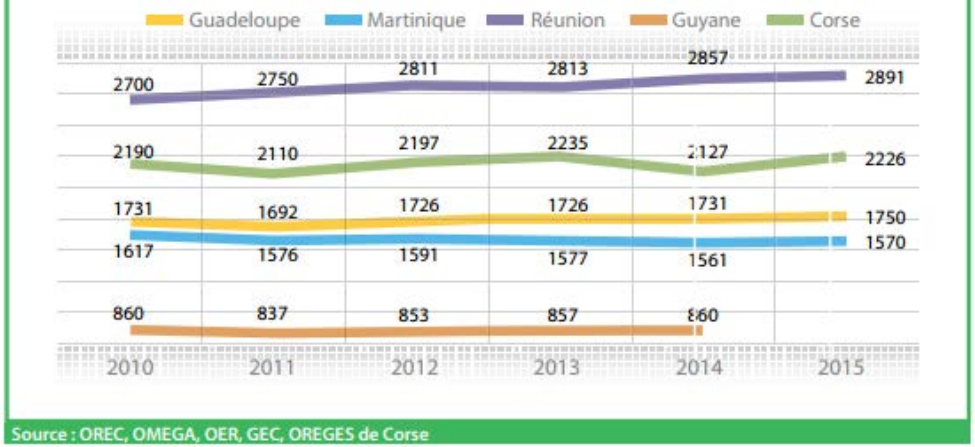


- These departments are called « Not Interconnected Areas » (because not connected to the Metropolitan electrical network) and have particular legislations. These areas need a permanent equilibrium between energy production and consumption
- Because of their isolation and geographical specificities, which limit the size of the production tools, the energy costs are much more higher than in metropolitan France (about two times)
- In order to compensate for this extra-cost, the public authority has established a national fee for the « Contribution to power utility » (CSPE)

Source : Observatoire Régional de l'Energie et du Climat (OREC) - Publication 2016

DOM: POWER PRODUCTION FROM 2010 TO 2015

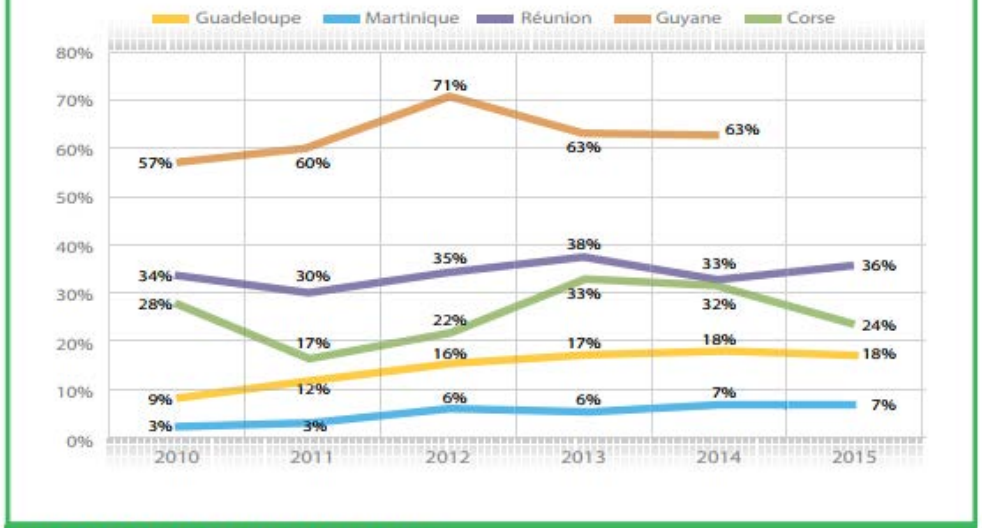
Figure 4 : Production d'électricité dans les ZNI en GWh



Source : OREC, OMEGA, OER, GEC, OREGES de Corse

Les données 2015 ne sont pas disponibles pour la Guyane.

Figure 5 : Part de la production d'origine ENR dans les ZNI



Source : OREC, OMEGA, OER, GEC, OREGES de Corse

Les données 2015 ne sont pas disponibles pour la Guyane.

- Similar power productions in Guadeloupe and Martinique
- Martinique (photovoltaic and bagasse) and Guadeloupe (photovoltaic and geothermal energy) have the lowest amounts of renewable energies
- If the proportion of renewable energies is increasing, for the moment, it remains only an additional support to the fossil energies (fuel and coal), which are the main sources of energy for power production, especially in Guadeloupe and Martinique
- From an environmental point of view, these territories represent biodiversity reservoirs which must be taken into account and preserved

THE ENERGETIC CHALLENGE

- Law of the Energy Transition (2015): 50% of renewable energy in the French Overseas Departments in 2020
- Energy autonomy in 2030
- The sensitivity of the electrical systems, observed in these areas, has conducted **to limit to 30%** of the power injected in the electrical network the contributions of the intermittent energies (solar, wind), sources of weakness of the network (ministerial ruling on 23/04/08). So, it is necessary to develop smarts grids in order to best manage the energetic mix
- The objectives of the law of the Energy Transition cannot be attained at a sustainable cost for the collectivity, without the development of the geothermal energy, continuously available (24h/24), and at a competitive cost
- Perspectives : 100 MWe in 2023 in the French Overseas Departments

USES AND ADVANTAGES OF THE GEOTHERMAL ENERGY

Uses

- Power / Heat / Cold

Advantages

- Local and non intermittent renewable energy
- Competitive cost of production
- Important potential
- Low land occupation
- Limited impacts
- Source of local jobs
- Reduced and stable operational costs

Weaknesses

- Delays
- Important initial investments (high costs for drilling wells)
- Geological risks
- Societal acceptance (environmental integration)

INDUSTRIAL CHALLENGE FOR THE DOM

- Geothermal energy is a mature technology at the worldwide scale:
  13 GWe installed in 2015 (against 18,5 GWe expected)
  70 GWe are expected in 2050 (+70 GWe EGS)

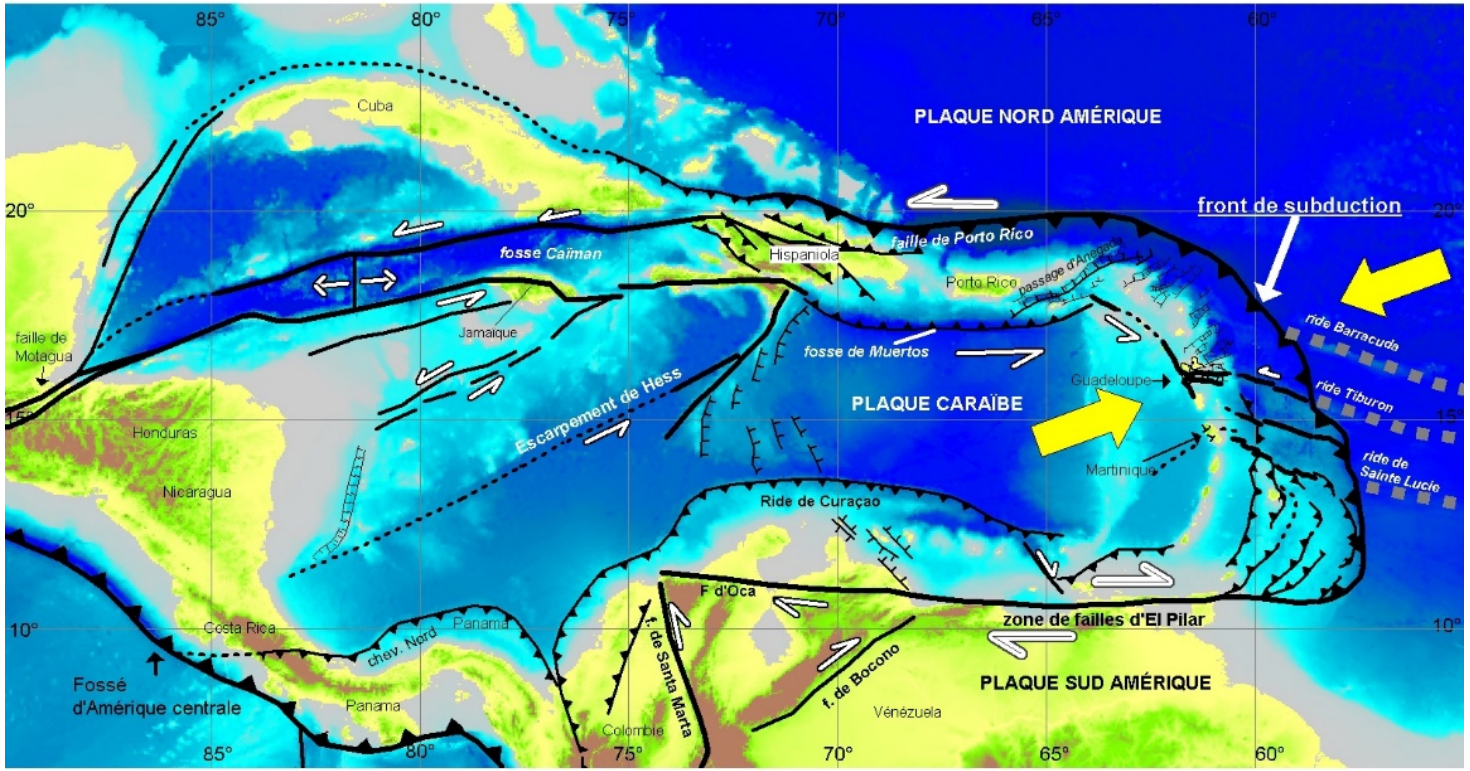
- It must be noted that, in the French Overseas Departments (but also in all the Caribbean islands), new geothermal projects have difficulty being developed (the Bouillante geothermal plant is the alone example in this region)

- The situation for the French Overseas Departments is particular:

  - a specific geological and geographical context
  - insular constraints (small power stations and no possibility of external connection)
  - important ecological sensitivity and population density in the coastal areas => strengthened environmental requirements

- It is necessary to develop tailor-made geothermal projects

GEODYNAMIC CONTEXT OF THE LESSER ANTILLES VOLCANIC ARC



faille majeure

faille majeure supposée

faille normale

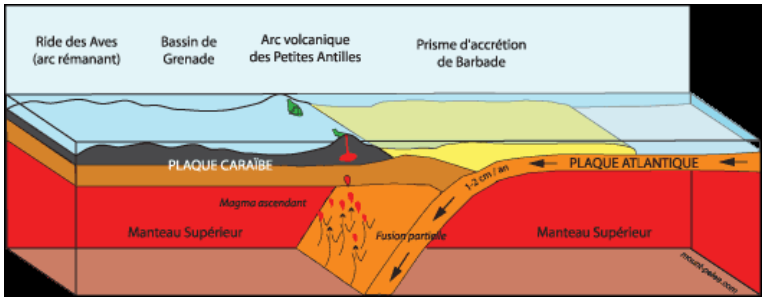
faille inverse

faille décrochante

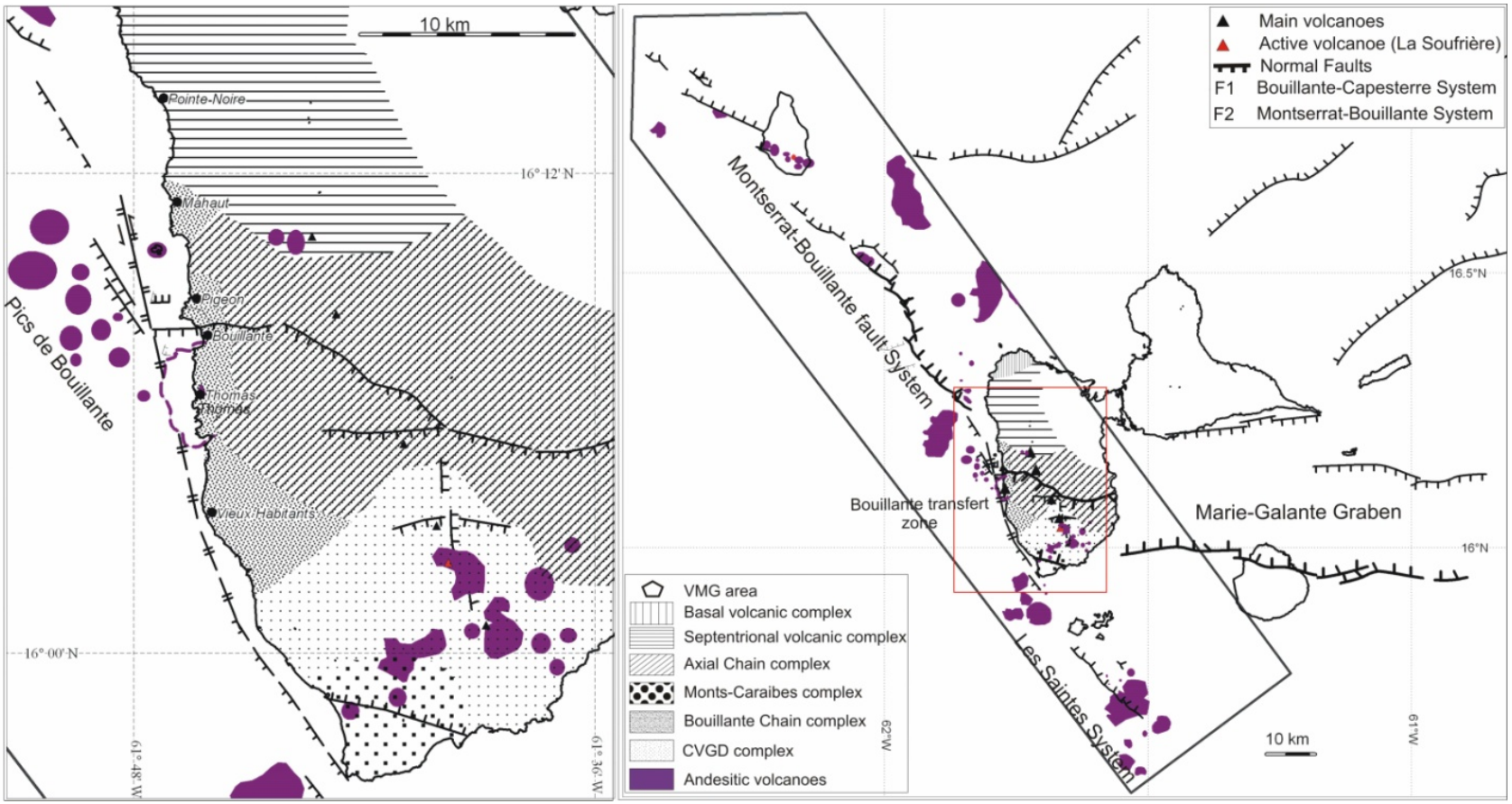
ride (ancienne faille transformante)

chevauchement de la plaque Caraibe sur les plaques amériques

Mouvement des plaques



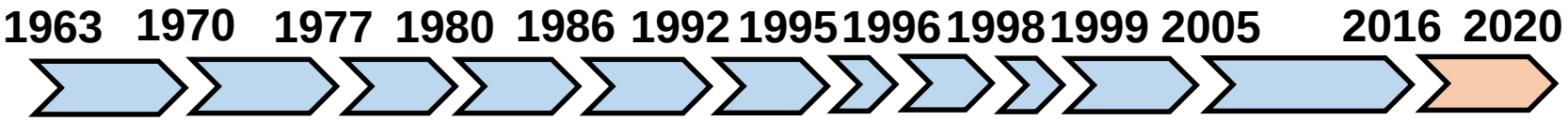
VOLCANO-TECTONIC REGIONAL CONTEXT



- Location of the Bouillante field at the intersection of the transform fault system Montserrat - Les Saintes N160° and the fault system of the Marie-Galante Graben (E-W)

- Volcanic substratum: Bouillante volcanic chain (0,8 - 0,5 Ma) on the flanks of the “Axiale chain”

HISTORY OF THE BOUILLANTE GEOTHERMAL FIELD



BRGM + EURAFREP exploration

BRGM Exploration

BRGM investigation works (1995-2016)

BO-4 thermal stimulation (1998-1999)

ORMAT MT works + tests on wells

EURAFREP : wells BO-1, BO-2, BO-3, BO-4

GB (2000-2002) : wells BO-5, BO-6, BO-7

Partial reinjection into BO-2, since 2014

EURAFREP-EDF (1980-1986) : Bouillante 1 construction

GB (2003-2005) : B2 unit construction

EDF (1986-1992) : B1 exploitation (4.2 MWe)

GB (since 1995, with B1 complete rehabilitation in 1996) : B1 exploitation (4.5 MWe)

GB (since 2005) : B2 exploitation (11 MWe)

1998: ≈ 2% island annual electricity

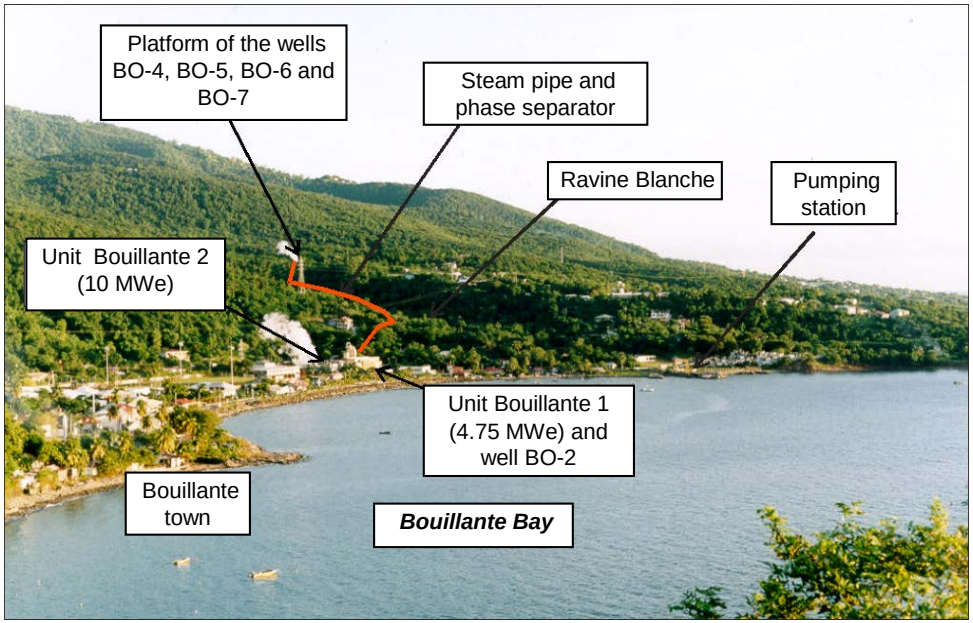
2005-2020: ≈ 5 à 6%

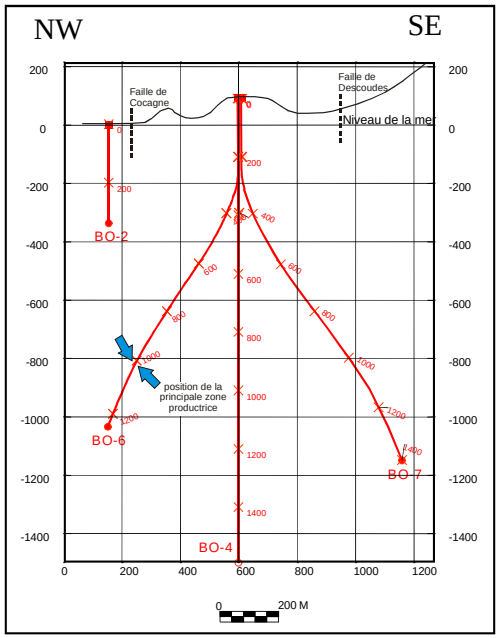
Géothermie Bouillante S.A. - GB (BRGM majority group, EDF group) : 1995 - 2016

GB (64% ORMAT, 15% BRGM group, 21% Caisse des Dépôts et Consignations) : since 2016

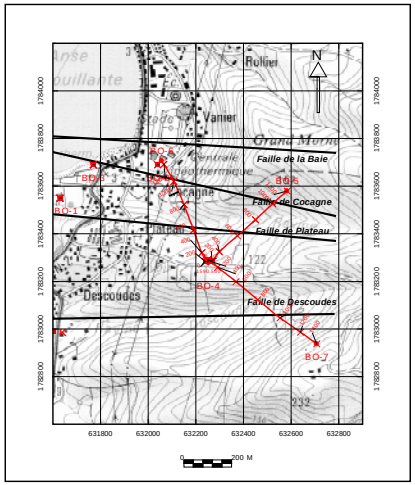
Production wells (in red)

BOUILLANTE CURRENT CONFIGURATION





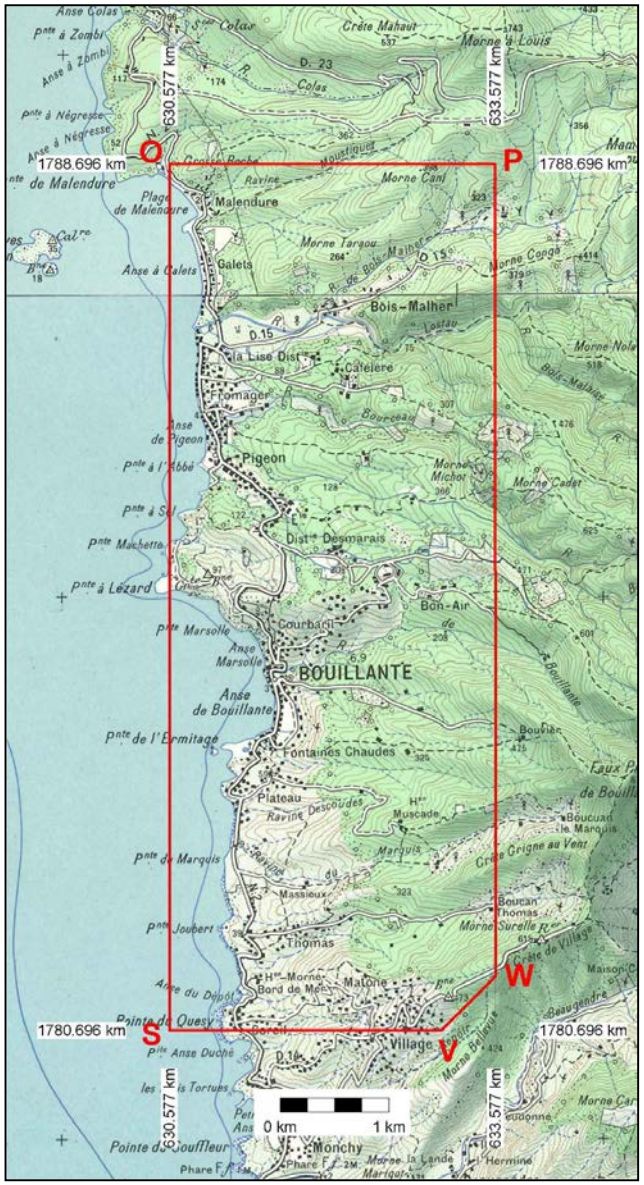






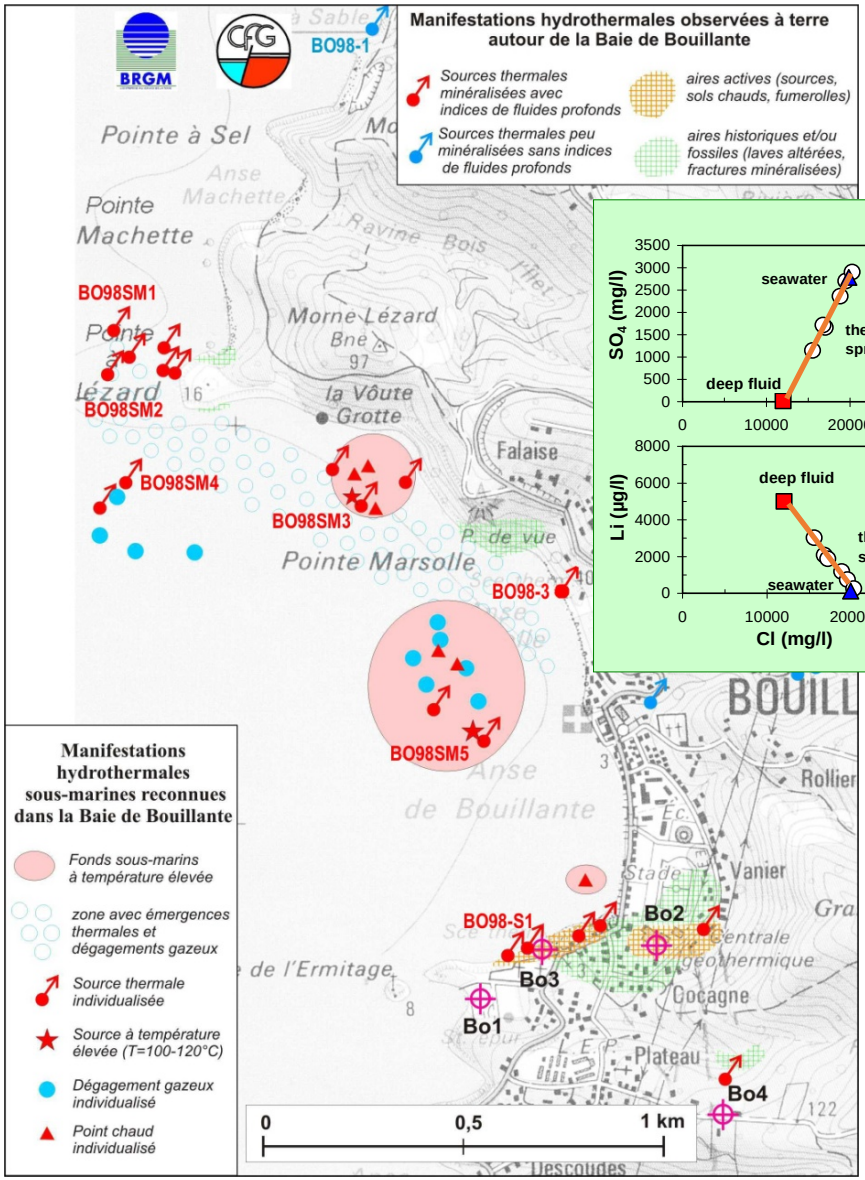
METHODS OF SURFACE EXPLORATION USED IN THE BOUILLANTE AREA

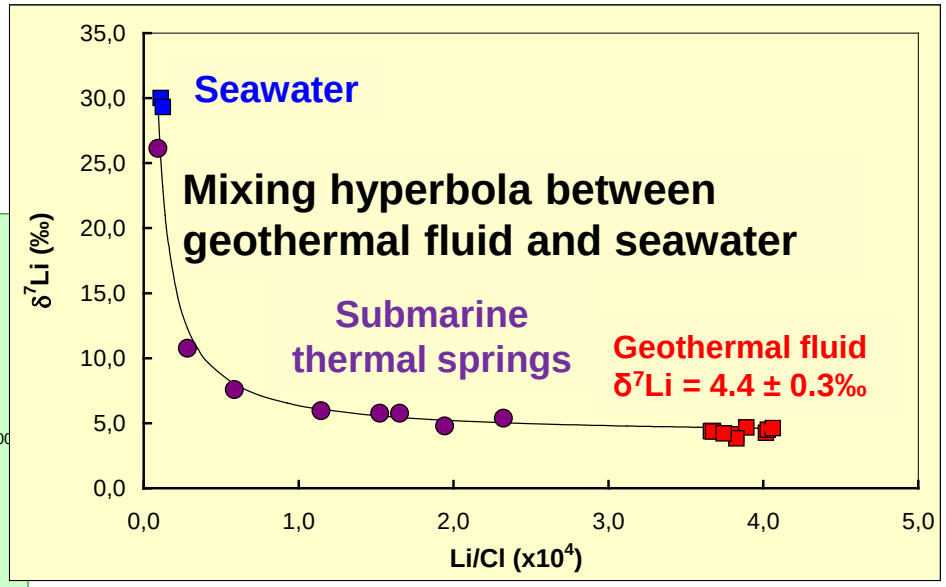
Bouillante concession (17 June 2009) for 50 years



- **Geology**
  - Structural geology (1996-2013)
  - Hydrothermal manifestations (mainly in 1996-2008)
  - Age determinations, especially in 2006-2008 and 2013 (Verati *et al.*, 2013) : the Bouillante geothermal system could have started since about 0,3 Ma, according to several samples of adularia collected in a hydrothermal breccia
- **Geophysics**
  - High-resolution marine reflection seismic (2003)
  - Offshore and onshore magnetic survey (2003-2005)
  - Dipole-dipole electrical panel (2004-2007)
  - Broad-band seismology (2004-2013)
  - MT survey (2017)
- **Geochemistry**
  - Geochemistry of thermal waters (1996-2013)
  - Chemical analyses of the soil gases (2003-2004)

SYNTHESIS OF GEOCHEMICAL EXPLORATION CAMPAIGNS (Sanjuan, 2001; Millot *et al.*, 2010)

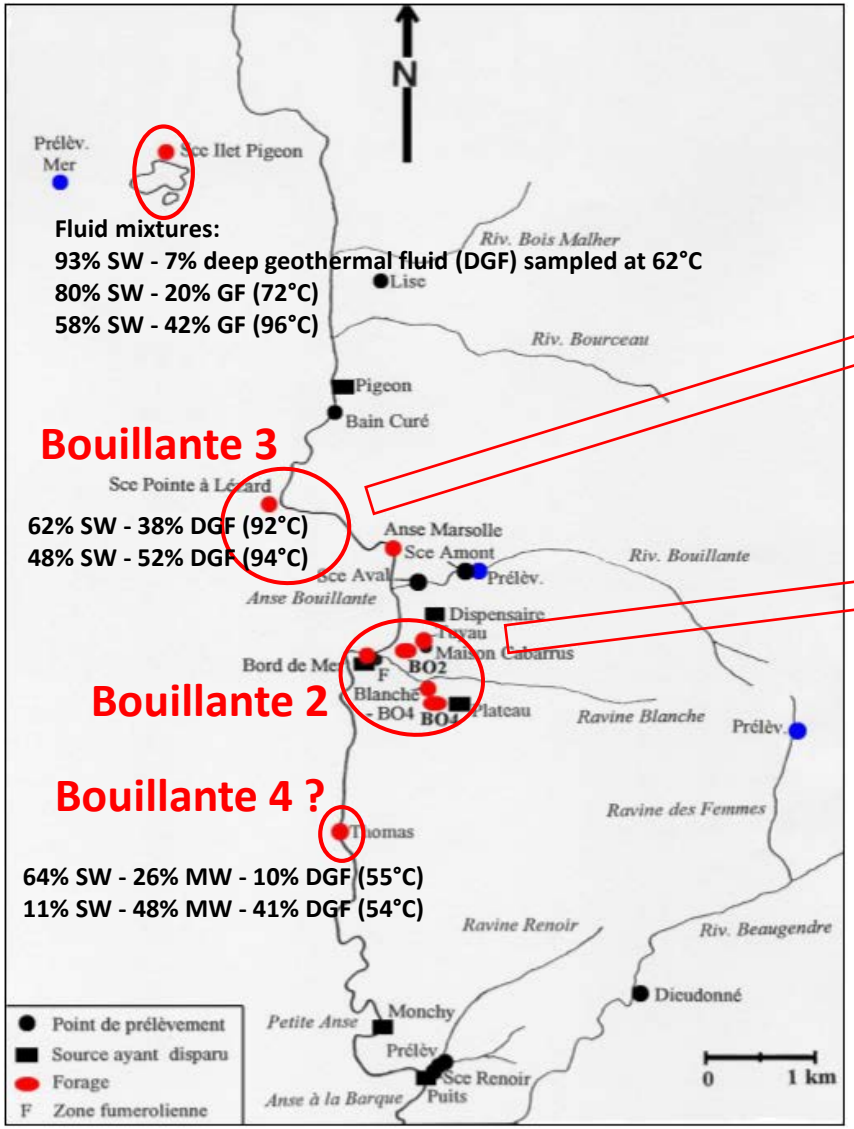


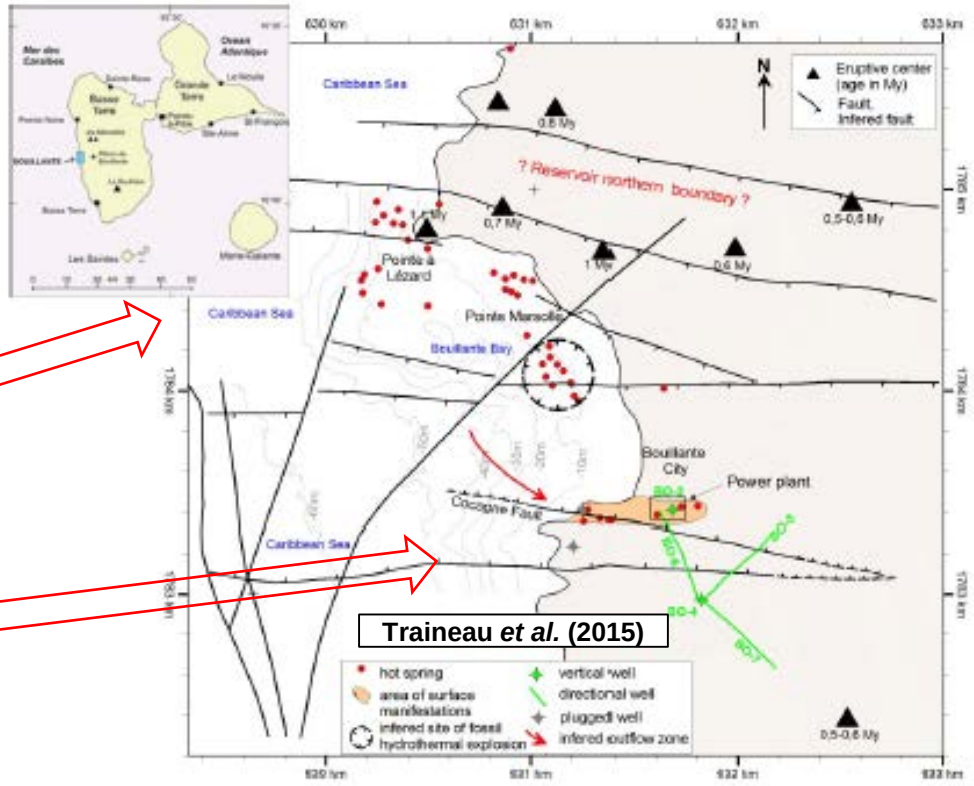


- The deep fluid discharged from the Bouillante production wells is constituted of **58% seawater et 42% freshwater**
- The deep fluid has acquired its chemical and isotopic composition after interaction with volcanic rocks **at 250-260°C**
- The water of all the submarine thermal springs is constituted of a mixing between this type of fluid and seawater

→ this suggests the existence of a big common geothermal reservoir

MAIN AREAS OF DEEP GEOTHERMAL WATER ESCAPES IN THE BOUILLANTE REGION (Sanjuan, 2001)





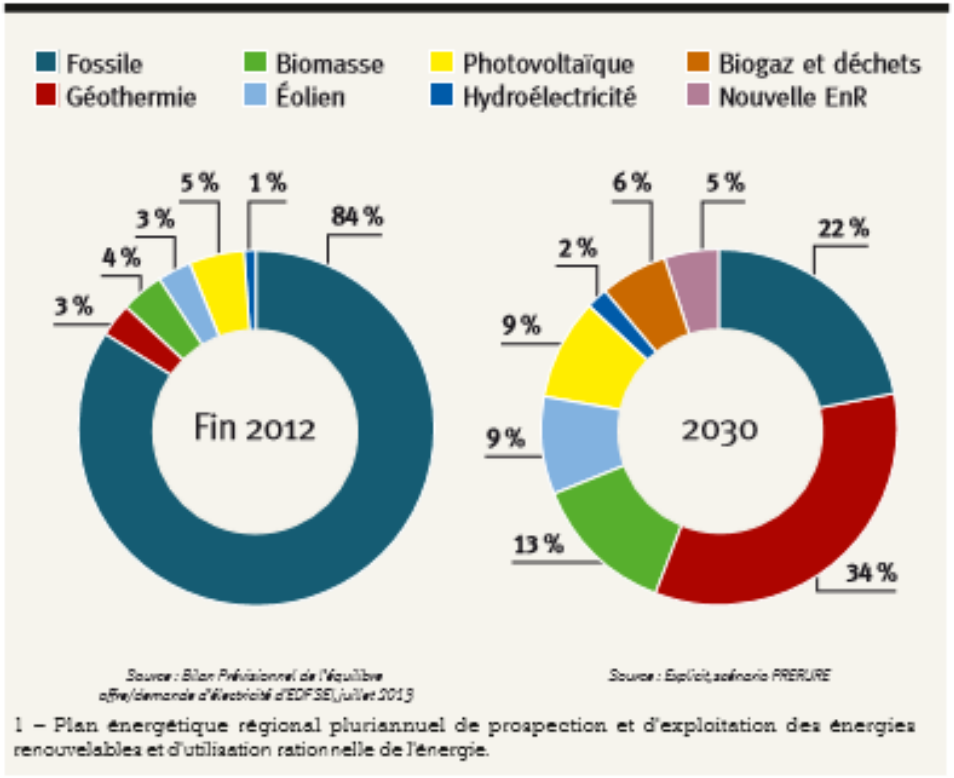
- **Bouillante 2 extension:** new exploitation wells (10 MWe)
- **Bouillante 3:** 3-4 exploration wells to drill, in the North of the bouillante Bay (30 MWe expected at mean term)
- **Bouillante 4:** in the South of the Bouillante Bay (15 MWe?)
- The installation of 60 MWe represents an investment of about 180 M€ (3 M€/MWe), with local expenses (civil engineering, technical subcontracting…). The power stations can generate an annual turnover of about 60 M€, with an important impact on the local employment (direct jobs, maintenance)

GUADELOUPE ISLAND: TOWARDS GREEN ENERGIES

- Bouillante annual current electricity production: **80-110 GWh** (**15 MWe, 120-130 tons/h steam**)

- Several monitoring methods, modelling works and fluid reinjection have been developed to optimize and secure the Bouillante geothermal exploitation:
  - monitoring methods: soil thermometry, geophysics (seismic, gravity, InSAR…), fluid geochemistry (production fluids and fluids discharged from neighbouring thermal springs…)
  - modelling works: 3D-geological modelling, hydro/thermo/geochemical modelling of the Bouillante reservoir and wells, including results from chemical tracer tests
  - operational partial reinjection fluid (100 tons/h), since 2015

Energetic mix in 2012 and foreseen electrical mix in 2030 (in % network production)



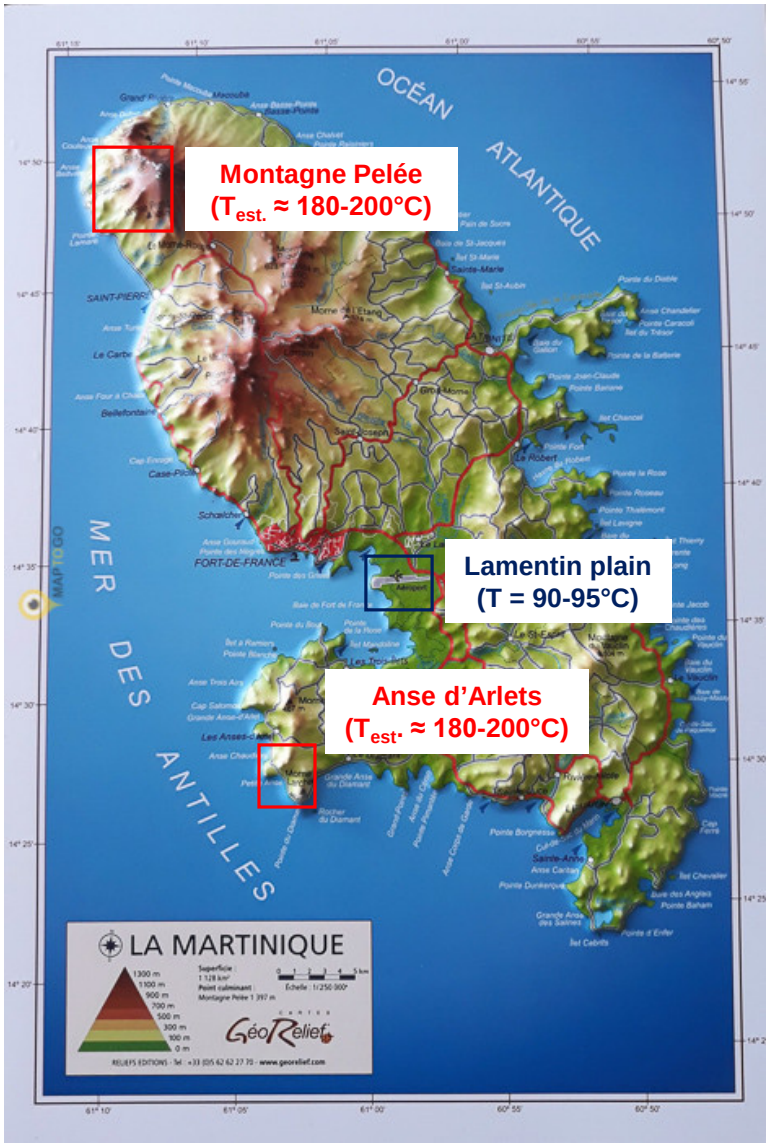
1 – Plan énergétique régional pluriannuel de prospection et d'exploitation des énergies renouvelables et d'utilisation rationnelle de l'énergie.

Source: « Décryptages Janvier / Février 2014, lettre de la Commission de Régulation de l'Energie (CRE) »

EXPLORATION WORKS IN THE MARTINIQUE ISLAND

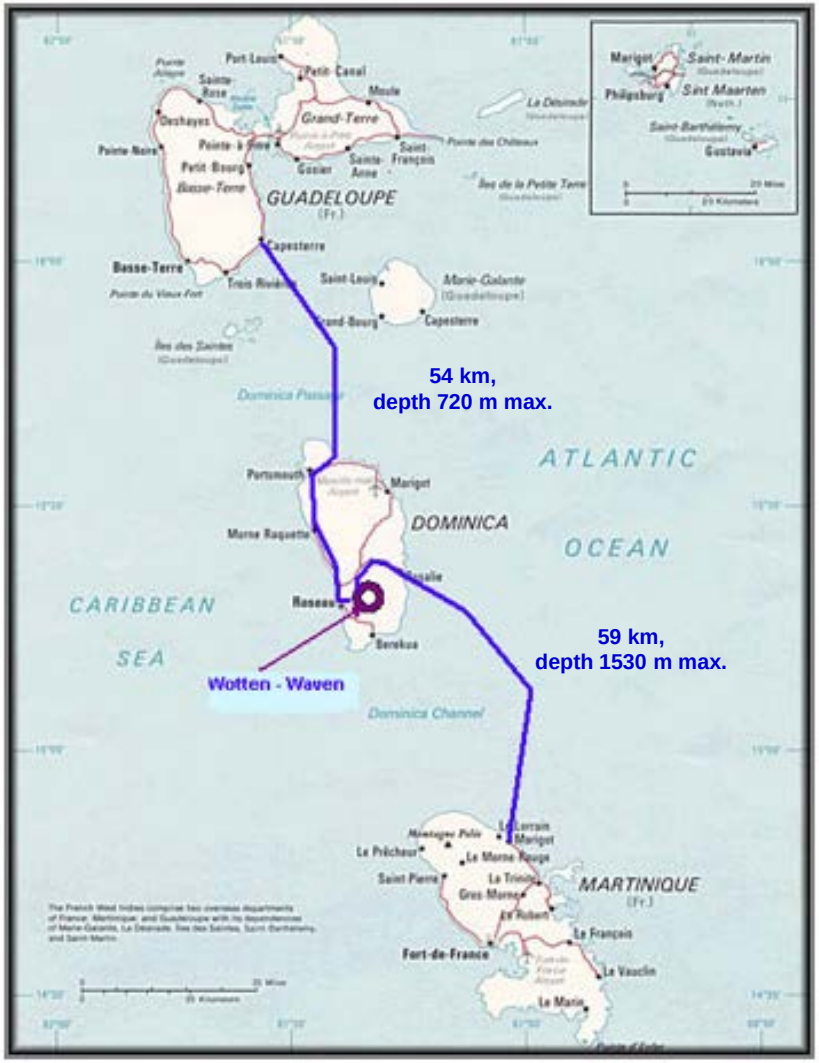
History

- **1967-1970:** BRGM surface geothermal exploration (geology, fluid and gas geochemistry, geophysics) in numerous areas of the island (Lamentin plain, Montagne Pelée, Anse d'Arlets, Morne Rouge, etc.) and drilling of **an exploration well (about 90°C) in the Lamentin plain**
- **1977-1985:** new BRGM evaluation of the geothermal potential
- **2001:** drilling of **3 exploration wells in the Lamentin plain ($T_{max.}$ = 95°C in only one well)**
- **2002-2003:** new BRGM geothermal exploration and determination of **two favourable areas for high-temperature geothermal exploitation (Anse d'Arlets, Montagne Pelée, temperatures estimated at about 180-200°C)**
- **2010-2020:** additional BRGM exploration works in the Lamentin plain and Anse d'Arlets area for geothermal developments at low (cold production) and high-temperatures (electricity production), respectively



No exploited area for the moment, but some requests of permit for geothermal developments

POSSIBLE GEOTHERMAL CONTRIBUTIONS FROM THE DOMINICA ISLAND?



- Develop geothermal energy for power production in the Dominica Island (3 promising exploration wells in the Roseau Valley area, funded by AFD and drilled by Iceland Drilling, in 2011)
- 20 MWe for Dominica (less than 100 €/MWh)
- It could be envisaged to export a part of produced electricity to the Guadeloupe (40 MWe) and the Martinique (40 MWe) French Islands, *via* an interconnection using submarine cables (450 M€)

MAIN CONCLUSIONS

- Successful initiative of the geothermal energy progressing in the Guadeloupe island, transposable to the Martinique island. The development of geothermal electricity in the Lesser Antilles, **a not intermittent renewable energy**, is well adapted for these islands
- The regulatory framework associated with the high-temperature geothermal energy is adapted. However, particular attention must be paid on **the lead times of procedures**
- The incentive framework, which can be today improved (creation of GEODEEP funds), has not lead to the fast emergence of projects, the current limits being **the risk coverage**, **the exploration financing**, the community interests**…**
- It is necessary to develop **a really sustainable geothermal energy (the best environmental integration!) in these areas**
- **Creation of a "Centre of Excellence in Geothermal Energy for Caribbean countries" (INTERREG V - TEC program)** to promote and develop geothermal energy in these countries

MAIN PARTNERS, COLLABORATION, DELIVERABLES, …

Main deliverables (1996-2016) :

- about 20 scientific international papers
- about 60 BRGM scientific and technical reports
- about 60 oral presentations in international scientific congresses
- several vulgarisation articles
- 5 PhD Thesis (Antilles and Poitiers Universities)
- about 20 internship reports (Masters 1 and 2, “Grande École”,…)



Thank you for your attention !

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