Hydrothermal alteration: marker of paleo-hydrothermal fluid circulation. Towards a better understanding of Vieux-Habitants geothermal area (Basse-Terre, Guadeloupe).

Gildas Beauchamps[1], Béatrice Ledésert[1], Ronan Hébert[1] and Danièle Bartier[2]

[1] Geosciences and Environnement, University of Cergy-Pontoise, France

[2] Georessources, University of Lorraine, France

gildas.beauchamps@u-cergy.fr

Keywords: hydrothermal alteration, clay minerals, petrography, Guadeloupe.

ABSTRACT

Due to its geodynamic location in the Lesser Antilles arc, Basse-Terre of Guadeloupe (France, Lesser Antilles) displays an active volcanism. The geological context in the west coast of Basse-Terre is favourable for the development of geothermal energy associated to power generation. Thus, thirty years ago, the Bouillante geothermal field was brought into production and now produces around 15 MWe (Bouchot et al., 2010).
In order to increase the geothermal electricity generation of Guadeloupe, investigation is taking place over Vieux Habitants area, a few kilometres southward of Bouillante.
This investigation is currently supported by GEOTREF project. This project is conducted by nine french laboratories (Mines Paristech, ENS Paris, GeoAzur, Georessources, IMFT, IPGS, LHyGes, UAG, UCPGEC) and two french industrial companies (Teranov and Kidova). It is funded by the ADEME in the frame of "les Investissements d'Avenir" program.
As part of the characterization of deep fluid circulations, we focused this study on areas that have been subjected to paleo-hydrothermal alterations. These zones represent potential exhumed deep fluid pathways.
The main task of this study is to understand the different processes of hydrothermal alteration that took place in different types of volcanic host-rock by understanding the geochemical transfers between hydrothermal fluids and the host-rock.
To achieve this task, field-work combined to laboratory studies will allow petrographic characterization of this alteration by means of microscopic study, XRD, and also geochemical analysis.

1. GEOLOGICAL CONTEXT

Guadeloupe is located in the Lesser Antilles volcanic arc, which is related to an oblique subduction of the Atlantic oceanic lithosphere under the Caribbean plate with a relatively slow rate of about 2 cm/yr (DeMets et al., 2000).

Lesser Antilles are composed of two volcanic arcs, the external one was active from Eocene to Early Miocene and the Inner arc is active from Late Miocene until present. The west part of Guadeloupe, called Basse-Terre, belongs to the central segment of the active volcanic arc.

The volcanism in Basse-Terre is shifting from north to south for the last 3 Ma. Nowadays, volcanic activity is represented by La Soufrière volcano.

Six main volcanic massifs are composing the Basse-Terre, from north to south: the Basal Complex that is the oldest one, dated at 2.7-2.8 Ma, the Septentrional Chain (1.1-1.8 Ma), the Axial Chain (0.6-1.0 Ma), the Bouillante Chain (0.7-0.9Ma), the Grande Découverte-Soufriere Massif (<0.6 Ma) and the Monts Caraïbes (0.4-0.5 Ma) (Samper et al., 2007).

The tectonic of Basse-Terre is represented by four main fault systems (N50 to N70, N90 to N110, N120 to N140 and N160 to N10) (Feuillet et al., 2001). As the Bouillante geothermal reservoir shows, hydrothermal resource is preferably located at the intersection of main faults systems (Calcagno et al., 2011).

Several lithologies occur on Basse-Terre, such as massive lava flows, pyroclastic deposits, and debris-flow (or lahars) due to gravitational instability.
Basse-Terre lava flows have a composition from mafic to intermediate with a SiO_2 content from 47 to 64 wt.%, with mainly andesites, basaltic andesites, few basalts, and only one dacite from the Axial Chain (Samper et al., 2007). Lavas have 25 to 65% content of phenocrysts, being mainly plagioclase ± clinopyroxene, ±orthopyroxene, ±oxides, with a microlitic and oxide-rich groundmass (Samper et al., 2007).

2. SURFACE OCCURRENCE OF POSSIBLE MARKERS OF HYDROTHERMAL ALTERATION

2.1 Methodology

In order to study the surface occurrences of hydrothermal alteration, we focused on about 10 outcrops located on Basse-Terre island, from the Basal Complex in the north, to Monts Caraïbes in the south. In that way, by looking at the basal complex, for which its mineralogy implies a burying at more than 2 km deep, we can establish an analogy with the present geothermal reservoir assumed to be located at a 2000m depth in the Vieux Habitants' area. Moreover, we looked at the variability of the hydrothermal alteration according to the lithology of the host-rock (andesite lava flows, debris-flows, pyroclastic deposits).

Firstly, we performed field work combined with precise sampling of the occurrences of suspected hydrothermal alteration. We sampled different types of altered rock, such as the fillings inside the veins along with its host-rock, the pervasive and homogeneous alterations through the rock, and also fresh rock that did not experienced hydrothermal alteration. XRD analyses (Géoressources laboratory, Nancy), have been carried out both on unaltered and altered samples. Thin-section observation by optical microscopy is in progress.

2.2 XRD results

XRD altered whole rock analyses display secondary minerals such as silica polymorphs (cristobalite, trydimite, quartz), Al-sulphates (alunogen). These minerals can be related to acid-sulphate fluid circulations (Rodgers et al., 2000; Salaun et al., 2011). In some samples, calcite and gypsum have been formed possibly by the remobilization of Ca from alkali-feldspar.

The XRD results on <2µm fraction from altered zones, show that smectite is the main clay mineral in samples (figure 1). However, it can be associated with kaolinite, an assemblage of kaolinite and halloysite, and sometimes illite.

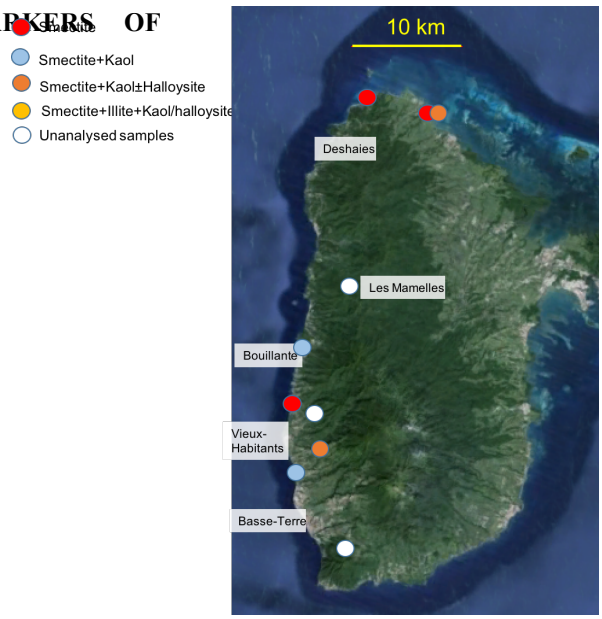

Figure 1: Map of the location of the first XRD results on <2µm fraction.

2.3 A first typology of clay minerals distribution

By studying about 10 outcrops that have possibly been subjected to hydrothermal fluid circulation, we distinguished three different types of occurrences, based on their distribution through the host-rock and their mineralogy:

- (a) injection of smectite into vertical fractures and its spreading laterally along horizontal planes (figure 2).

These horizontal planes can be discontinuities between different debris flow, or schistosity due to pressure-solution which forms in andesite lava flows that have been buried deep enough.

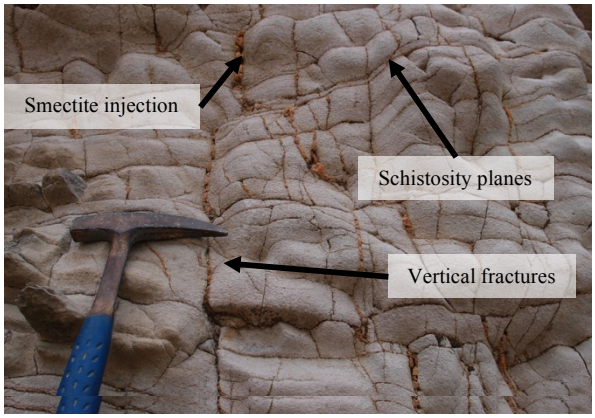

Figure 2: Smectite injection in a fractured andesite lava flow (Anse-Tillet).

- (b) alteration of the host rock in the form of vein and replacement of the pre-existing material without an infilling by clay (figure 3). In that case, the <2µm fraction is not entirely composed of smectite, but of a mixture of 90%

smectite, and 10% of an assemblage of kaolinite and halloysite.

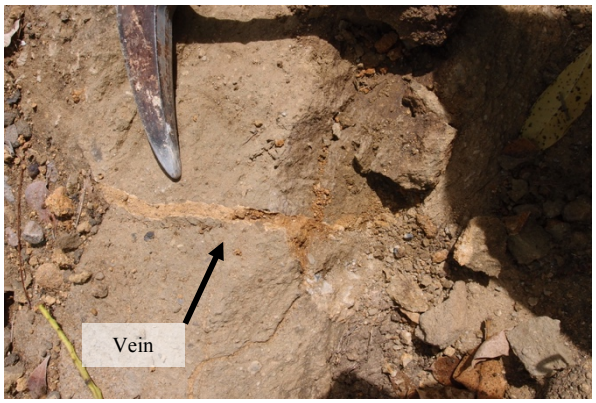

Figure 3: Vein developed through a fine-grained debris-flow (Schoelcher track).

- (c) pervasive alteration of the host rock, in a diffuse way, where the matrix contains about 85% of smectite and 15% of kaolinite (figure 4, in a debris-flow at Rocroy beach).

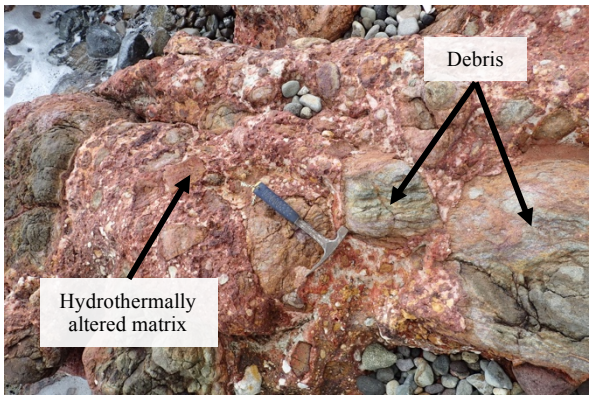

Figure 4: Diffused hydrothermal alteration in a debris-flow host-rock at Rocroy beach.

The first analyses suspect a specific mineralogy for the different types of occurrence identified, but as few analyses have been made for now, this typology has to be upgraded and validated by the future results.

3. CONCLUSIONS

Characterization of mineralogy and distribution of hydrothermal alteration by looking at surface improve understanding hydrothermal fluid circulation in deep reservoir. However, the main problem of this approach is to deconvolute the hydrothermal signature from the meteoric alteration, which is intense in this tropical climate. In this way, detailed petrographic and geochemical analyses have to be performed such as mass balance study between altered rocks and fresh samples.

REFERENCES

Bouchot V., Sanjuan B., Traineau H., Guillou-Frottier L., Thinon I., Baltassat J.M., Fabriol H., Bourgeois B., Lasne E. (2010), "Assessment of the Bouillante Geothermal Field (Guadeloupe, French West Indies) : Toward a Conceptual Model of the High Temperature Geothermal System", Proceedings World Geothermal Congress 2010, Bali, Indonesia, April 2010.

Calcagno, P., Bouchot, V., Thinon, I., & Bourgine, B. : A new 3D fault model of the Bouillante geothermal province combining onshore and offshore structural knowledge (French West Indies). *Tectonophysics*, *526*, (2012), 185-195.

DeMets, C., Jansma, P. E., Mattioli, G. S., Dixon, T. H., Farina, F., Bilham, R., ... & Mann, P.: GPS geodetic constraints on Caribbean-North America plate motion. *Geophysical Research Letters*, *27*(3), (2000), 437-440.

Feuillet, N., Manighetti, I., & Tapponnier, P. : Extension active perpendiculaire à la subduction dans l'arc des Petites Antilles (Guadeloupe, Antilles françaises). *Comptes Rendus de l'Académie des Sciences-Series IIA-Earth and Planetary Science*, *333*(9), (2001), 583-590.

Salaün, A., Villemant, B., Gérard, M., Komorowski, J. C., & Michel, A.. Hydrothermal alteration in andesitic volcanoes: trace element redistribution in active and ancient hydrothermal systems of Guadeloupe (Lesser Antilles). *Journal of Geochemical Exploration*, *111*(3), (2011), 59-83.

Acknowledgements

We would like to acknowledge the ADEME for funding this work in the frame of "Les Investissements d'Avenir" program.